SUMMARY REPORT OF THE TWENTY-NINTH MEETING OF THE CIVIL GPS SERVICE INTERFACE COMMITTEE (CGSIC)

Sponsored by: The Office of the Assistant Secretary for Transportation Policy (OST/P-7) and the United States Coast Guard (USCG) Navigation Center (NAVCEN)

Dates: 18-20 March, 1997

Location: Ramada Plaza Pentagon, 4641 Kenmore Avenue, Alexandria, VA 22304

Chair: Joseph Canny, Deputy Assistant Secretary for Transportation Policy
Deputy Chair: Captain James Doherty, Commanding Officer, Coast Guard Navigation Center

Council Representatives:
Air: David Olsen, Federal Aviation Administration
Land: James Arnold, Federal Highways Administration
Marine: CAPT Mike Myers, Coast Guard Headquarters
State: Henry Baird, Department of State
GIAC: CAPT Lewis Lapine, National Geodetic Survey
International Information Subcommittee:
    Chair: George Preiss, Orbit Communications, Sweden
    Vice-chair: Georg Weber, Institute for Applied Geodesy, Germany
    Secretary: Mike Savill, Northern Lighthouse Board, Scotland, UK
Timing Subcommittee:
    Chair: Dr. Wlodek Lewandowski, Bureau International des Poids et Mesures, France
    Co-chair: Lisa Nelson, National Institute of Standards and Technology
Executive Secretary: Rebecca Casswell, Coast Guard Navigation Center

Agenda: The agenda for the 28th meeting is included as Appendix A.

Attendance: A list of registered attendees is included as Appendix B.

18 March 1997
MEETING OPENING

Mr. Joe Canny, Chair, opened the 29th Meeting and welcomed the attendees.

POLICY SESSION
Session Chair: Joseph Canny

Status of the CGSIC
Captain James Doherty, Deputy Chair.

CAPT Doherty's slides are included in Appendix C.
CAPT Doherty stated the CGSIC contributes to the overall management of the GPS. The CGSIC continues to be over 400 members, representing a good portion of the United States in industry, government, and a lot of civil user needs, and represents over 50 other countries.

CAPT Doherty then reported on issues raised at the last meeting.

1) Potential power reduction on the Block IIR satellites- Following the meeting the GPS JPO put out a technical paper which is included as Appendix C, stating how the power is managed differently in the new satellites.
2) Second Civil Frequency and civil use of L2- A recent press release, Appendix C, guarantees carrier phase on L2 for civil users and states a commitment to work to identify a second civil frequency.
3) NANU standardization- 2SOPS developed templates for NANU notification of the satellite and the consultation health and a questionnaire on for NANU users. (See Lt. Barker's report.)
4) Pacific rim participation- a need was identified for more participation from the Pacific rim into the IISC. The Australian GNSS is hosting an IISC meeting in Canberra at the end of June.
5) CGSIC Executive Business Plan (EBP)- The Executive Board approved the EBP (included in the 28th meeting summary) in September. The mission, vision, and some goals for the committee are contained in the EBP.
6) GPS interference testing- There is a process in place to evaluate how testing will be done, when it will be done, and where, making sure that testing can be done to assure the military use of the system as well as to assure the civil use while the testing is underway.

A Performance Task Force will be formed to complete the Standard Operating Procedures for the Committee. These should be available at the September meeting.

Our Executive Business Plan states the CGSIC is 1) to share information from US government GPS system providers and augmentation service providers with user, 2) to share information from user with the US government provider of the system and it augmentations, and 3) to provide a forum for varied users to share information with each other.

DOT Policy Update
Mr. Joseph Canny, Deputy Assistant Secretary for Transportation Policy

There have been many important events in GPS policy over the past several months, much of it a result of the Presidential Decision Directive signed by President Clinton almost a year ago. Perhaps the most important event was the forming of the Interagency GPS Executive Board, which is responsible for the overall management of the GPS system, to serve both the national security and civilian users. The Board will eventually oversee the relations between The Department of Transportation, the lead civil agency, and the Department of Defense, and give greater breadth to the overall management of the GPS system. The Board's charter was signed by former Secretary of Transportation Federico Pena, before he left office, and by Secretary of Defense William Cohen.

The initial meeting for the Executive Board is scheduled for 28 March. It will include not only the DOD and DOT, but also the Department of Commerce, the Department of State, NASA, and several others. This broader perspective on GPS should assure proper policy guidance to meet the needs of a whole range of user communities.

The second development is that a series of international consultations were initiated under the leadership of the Department of State. These have been government-to-government meetings, beginning with a meeting in Tokyo with the Japanese Government last August, followed by a meeting in December in Moscow with Russia, and a meeting last month in Brussels with representatives of the European Union. In each case, an agenda was set covering issues of mutual concern. The consultations covered the use of GPS, the development of augmentation systems, interest in the interoperability of different systems as they evolve, and other questions pertaining to the world policy direction and guidance for GPS and its augmentations. In each case a follow-on meeting has been scheduled. Those follow on meetings will be in Washington over the next three months.

The international consultations have been very helpful in getting a new interagency focus on GPS with other countries. In some cases, agencies that came together to meet the U.S. delegation had not met together before. Meeting the US representatives was the forcing event that pulled them together to talk about their mutual needs and concerns. The meetings have been a very successful initiative and will continue in the future.

The third major event in the GPS policy area was the report of a Presidential Commission, generally known as the Gore Commission. The Commission on Aviation Safety and Security Issues, chaired by Vice-President Gore, included among its members a former Secretary of Transportation, Professor Brad Parkinson -one of the fathers of GPS, and other distinguished scientists, administrators, and academics. It was formed to assist the DOT and the Federal Aviation Administration to develop stronger policy directives to deal with a wide range of aviation safety and security matters. The Commission published a final report about a month ago which recommended a wide range of initiatives that FAA will pursue over the next year.

With respect to GPS, the Commission recommended that the U.S. government should enhance the accuracy, the availability, and the reliability of the GPS system to accelerate its use in National Airspace System modernization and encourage its acceptance as an international standard for aviation. This strong endorsement of GPS added a further incentive to the FAA effort to make GPS the standard for navigation worldwide.

Second, the report suggested the US provide stronger, strategic leadership for the civil users of GPS. Specifically, the Commission recommended that civilian leadership be strengthened by establishing a Civil GPS Users Advisory Council, with representation from users and providers of GPS equipment and services, which would report to the

Interagency GPS Executive Board. It also recommended that the Administration work rapidly to develop international guidelines on the provision and use of GPS services, as called for in the Presidential GPS Decision Directive.

A GPS User Advisory Council is, to some considerable degree, what the CGSIC is. The authors of the report presumably knew of the CGSIC, but had something else in mind and attempts to clarify the this have not yet produced any answers. Whether the CGSIC should be reconstituted or augmented, to establish a more regular two-way communication system, for example, is not known.

The next recommendation suggests that greater redundancy is needed to enhance the ability of users to cross-check GPS accuracy and to verify the system's reliability. The report went on to suggest that the most effective means of achieving the redundancy use is to provide additional GPS precision ranging signals in space. The commission recommended that this capability be added to the FAA's WAAS system. The FAA has embraced this recommendation and is moving to implement it in the further development of the WAAS system.

The next recommendation was that the IGEB should resolve the remaining issues over funding and frequency assignment for a second civil frequency as quickly as possible, so that this needed improvement can be included in the next generation of GPS satellites. It was interesting to note that the Gore Commission recognized and gave official sanction to the need to establish a second civil frequency.

The final recommendation was that the GPS system must be protected from both intentional and unintentional interference. The Commission noted that GPS will be a core safety-of-life system and must be secure. That recommendation is in line with many other recommendations in the report concerning the security of the aviation system.

In summary, the report provided important guidance and targets to work towards in GPS planning and policy evolution over the next year or more.

The Departments of Defense and Transportation were able to resolve the second civil frequency issue at one level in February. DOT had been working with DOD for more than a year to identify a second civil frequency. A provision was added to the Block IIF contract to add a second civil frequency. The two departments had great difficulty in finding a frequency that will meet the user requirements, is financially feasible, and that is technically feasible. The chosen frequency must not cause unacceptable levels of interference with existing system or be interfered with by another system, but must also meet international spectrum allocation requirements.

The results of the efforts was a partial solution. Under it, a public statement was issued wherein the Department of Defense agreed to assure civil users guaranteed access to the L2 carrier phase signal. This will be documented in the next edition of the Federal Radionavigation Plan. Guaranteed L2 carrier phase signal availability will support the FAA WAAS and will be very important to the surveying community and other civil users.

The long term objective to have a full second civil frequency has not been dropped. A detailed plan for it will be worked over the next year. The GPS Joint Program Office in Los Angeles was directed to seek a proposal from a Block IIF contractor (Boeing). This will be something beyond the existing contract option and will consider the need to increase robustness of GPS by possibly adding another military frequency. Those studies are also underway within DOD.

Finally, there is a commitment of the President and the entire Administration to provide the most capable and reliable satellite navigation system that is possible, for use well into the next century. Having a fully coded second civil frequency will be a move in that direction. A very important policy development is the DOD decision to make a total review of the use of GPS and to revise its broad requirements for the system. This review is called the Capstone Requirement Effort (or GPS III). DOD is looking at the total potential of GPS and their needs to identify changes to GPS which might be appropriate.

DOD thought of the civil user at the start, asking DOT to take the lead in organizing the civil community input to identify the requirements. (Hank Skalski's presentation on this process is included in the Report.) This is a reaffirmation of the commitment to make GPS as effective and reliable as possible for the full range of civil users.

The DOD Perspective
Mike Shaw, Office of the Undersecretary of Defense for Space

Mr. Shaw's slides are included in Appendix D.

The Presidential Decision Directive directed the DOD to initiate a program to deter and prevent the hostile misuse of the GPS and its augmentations while promoting civil use. This capability does have military implications and we are going to have to live in the world where this capability is available to perhaps individuals in hostile countries.

Mr. Shaw then showed the slides included in Appendix D, which illustrated the targeting capabilities of GPS, which illustrated the capability of destroying a building with different levels of accuracy. The PDD states within the next decade S/A will be set to zero. Starting in the year 2000, an annual report will be provided to the President's Office of Science and Technology on the status of moving to set S/A to zero.

The second diagram shows accuracy with wide area and local area capabilities. It is the military's responsibility to deal with the greater accuracy. First, DOD must protect the use of GPS for its forces and its allies. It is a challenge from the civil community to see if military can handle a flexible environment to prevent the uses of the GPS for our adversary in a theater of conflict, and still provide the GPS service to civil users for peaceful purposes outside that theater of conflict. It is assumed that civil users will avoid that area of conflict. If they don't avoid the area of conflict, they will probably have problems other than the availability of GPS positioning. An illustration of the Security Program concept is shown in Appendix D.

Formation of the Interagency GPS Executive Board was directed by the PDD. The Charter was finalized 22 February, with the first meeting to be held 28 March. The purpose of the IGEB is to provide a overall national management structure for the dual-use aspects of GPS, and government augmentations to GPS. The Co-chairs are from the DOD and DOT, with the remaining members from State, Agriculture, Commerce, Interior, Joint Chiefs of Staff and NASA.

The IGEB functions are to:

- review the status and plans for the various departments on GPS and its argumentation to ensure an overall cohesion plan,
- approve dual use management policy,
- resolve interdepartmental issues,
- prepare status reports, and
- consult with US/foreign government and US industry.

The unifying thread to the DOD presentations is to assure you that the DOD is committed to providing a 24 satellite capability well out into the future. The Block IIF satellites will begin launch in the 2001 to 2002 time frame with a fifteen year life span. Some of them will operate out to the year

2025. Of equal importance is the Capstone Requirements Process where all the requirements, civil and military, will be integrated into the new GPS III, maintaining backwards compatibility.

Questions:

Keith McDonald asked what was meant by carrier phase in the press release.

Mike Shaw said he understood they have to be very clear about what carrier phase means. The intent is to document in specific detail, in the Memorandum of Agreement between DOD and DOT on the civil use of GPS, what the L2 agreement is to achieve, including specifically the definition of the carrier phase.

1996 Federal Radionavigation Plan
Heywood Shirer, OST Radionavigation Policy Staff

Mr. Shirer's slides are included in Appendix E.

Mr. Shirer stated that the Federal Radionavigation Plan (FRP) is the official source of U.S. radionavigation policy. It is jointly published by the Department of Defense (DOD) and the Department of Transportation (DOT) and covers all common use military and civil radionavigation. It is in a two year review cycle.

The systems covered in the FRP include GPS, Loran-C , Omega, DME , TACAN, Radiobeacons, ILS, and MLS. GPS is a system that is promoted by the Presidential Decision Directive and the Secretary of Transportation to become the world standard for navigation and positioning. Most of those other systems will be targeted for phase out in the near to long term future.

Release of the 1996 FRP was delayed awaiting the crucial decision on L2 and L5, hoping it could reflect that decision. The FRP is a international document with wide ranging impact, so they wanted to make sure that the FRP was current when it was released. The L2/L5 decision that was released in February will be reflected in 1996 FRP.

The Gore Commission Report recommended that the FAA develop plans to use some of the spectrum from the older systems that there are going to be phased out. This report is due in July 1997. However July is simply too late to put the entire report into the FRP, so the FAA will provide the primary information about the use of the spectrum, so that it can be concluded by the first week of April. Additional land mode requirements from the Intelligent Transportation System Office and the DOT will also then be available.

Secretary approvals from DOT and DOD should be accomplished by the third week in April. Once it is signed, it will be available through the Coast Guard Navigation Information Service. Approximately five weeks later hard copies will be available, but the official FRP should be released in April.

There are a lot of changes to the Federation Navigation Plan. It reflects the language on the PDD, and the formation of the Interagency GPS executive board. New sections on spectrum and on international consultations are also included.

The 1996 FRP will continue the policy of SPS being available worldwide free of direct charges. The PPS will still be available only to authorized users. The L2 carrier phase will be available to civil users and will not be disrupted. The Coast Guard DGPS reached initial operational capability on 30 January 1996.

ILS and MLS are now included under precision landing systems. It will include the GPS WAAS which will be available by the end of 1998 for Category I through nonprecision approach. By the end of 2001, WAAS will be fully operationally capable. The remaining phase out dates are included in Appendix ??.

The FAA is looking at the Local Area Augmentation System for CAT2 and CAT3. The technical feasibility has been determined, but there is no date yet set for when it will be fully operational. The ILS CAT2 and CAT3 systems will be sustained during the transition period. The system will be colocated during the transition period.

For Loran-C, the DOT policy is that it will terminate on 31 December, 2000. However, DOT is preparing a report to Congress in response to the Coast Guard Authorization Act of 1996. This report should be complete in seven months.

Omega will terminate on Sept. 30,1997. Notices were sent to the partner nations through the State Department.

The VOR/DME system is the backbone of the FAA navigation system and will remain primary means of navigation for nonprecision approach until GPS WAAS is approved, which should happen by the end of 1998. Radiobeacons, that will not be used for DGPS will be phased out by the year 2000. Aeronautical Nondirectional Beacons will be replaced by GPS by 2005. The FAA is developing a separate transition timeline for the phase out of these beacons in Alaska.

Questions:

Dee Anne Divis asked about the time difference between the Gore Commission recommendations and the phase out dates.

Answer:

The Gore Commission wants complete modernization of the system in the NAS by the year 2005. Both initial operational capability and the final operational capability will occur far before 2005. A primary system needs to be maintained and overlapped with GPS until the replacement system is proven to be robust enough, that it can be relied on as a sole means system.

GPS Interagency Advisory Council
CAPT Lewis Lapine, National Geodetic Survey

Since the release of the Presidential Decision Directive (PDD) last March significant events include: the creation of Interagency GPS Executive Board, talks about second civil frequency, and the start of bilateral international GPS meeting discussions. CAPT Lapine participated as Chair of the GPS Interagency Advisory Council. They also participated in the Federal Radionavigation Plan development.

The list of activities and dates are included in Appendix F.

On 3 October, the GIAC released a working paper called "Harmonization of Global Markets" for the Department of State's it result in the first meeting that was held in Japan.

The DOD and DOT agreement that assured the L2 carrier phase is important to civil agencies involved with post processing and high accuracy results. There are already lost cost receivers on the market that do carrier phase smoothing of the pseudorange. CAPT Lapine added that his group has been able to contribute because of the open door that Joe Canny provided through DOT.

Questions:

Joe Canny was asked what the time frame for L5 was.

Mr. Canny responded that they continue to look at a second civil frequency that will have acquisition code and a navigation message to be integrated into the Block IIF satellite procurement. They are trying to work through all issues with DOD and to have a plan within a year.

Dee Anne Divis asked how the IGEB relates to the DOD/DOT. Who does the IGEB relate to the management; who makes the final discussion; does the IGEB rubber stamp what been determined already?

Mr. Canny said they intended that IGEB would be decision making body.

Rolf Johannessen asked if Mr. Canny received the letter that the GNSS panel of ICAO sent from Australia last week, urging that the frequency should be one which that can be internationally protected.

Mr. Canny replied he did receive that communication and is aware of that interest and concern.

Ed McGann asked if there was anything to assure the FRP can be considered a reliable guide so that it can be used for planning.

Mr. Canny disagreed with that and considers the FRP has essentially been a reliable guide. There are attempts in the European community to develop a Radionavigation Plan. The basic FRP has a standard two year life and policy with intend to document for the longer term future, but also to reflect the evolution of policy during the course of a two year period.

GPS GENERAL

Constellation Sustainment
Lt. Col. Jerry Oney, Air Force Space Command

Lt. Col Oney's slides are included in Appendix G. They give the age and status of planes. Current constellation status for all six planes is green. The subsystems are green and the NAV payloads are good. The C Plane includes SVN28. The 14th Air Force is still deciding about what to do with that satellite.

The investigation into the launch failure is still ongoing. The General's brief should be on 2 April. The next launch is scheduled for July, depending on investigation results. The last Block IIA launch is scheduled for 1997.

NANU Improvements
Lt. Brian Barker, 2nd Space Operations (2SOPS)

Lt. Barker is responsible for NANUs , so if there are problems contact him. Since improvements in the system in 1996, there were 200 NANUs put out with only 11 containing errors. Since the last CGSIC, only two were incorrect. In the future they hope to eliminate the human error factor.

2SOPs has been accused of increasing satellite down time. Statistics show that they are decreasing down time.

A NANU questionnaire was distributed through the Coast Guard. They received a lot of responses. A lot people did not know what a NANU was. Since the last CGSIC they standardized the manual templates and created a macro to eliminate misspellings and other human errors.

There are ongoing talks with the FAA which include Lt. Col. Oney and Karen Van Dyke on automating the process. They are trying to get a World Wide Web Page through Falcon.

Questions:

Bernald Smith stated that it would be nice if forecast downtime was closer to actual downtime.

Lt. Barker said that they used the longer time to cover the users' interests.

George Preiss suggested if something is classified and cannot be answered, then it is better to say it is classified, than to keep quiet and say nothing. For instance, the way the question about PRN 30 was phrased.

Hank Skalski said the PRN number change was done before, and is not classified. There were problems with some receivers that need modification, but it will take a long time to do it. It was much easier to change the PRN number. Air Force Space Command should be saluted for not ignoring the civil world, and finding out if there will be a major impact on the civil user by doing this.

George Preiss requested that background be included with requests. He added that concerning down times, it might be better to say: 'as a percentage of the total available operational hours'.

Mr. Preiss suggested that the NANU types be made available on the Coast Guard Web page, and to send out a NANU explaining the various NANU types. He added that we should remember that not everyone can read Web Pages.

GPS Modernization
Hank Skalski, DOT Representative at Air Force Space Command

Mr. Skalski's slides are included as Appendix H.

Mr. Skalski said that he and the Air Force are asking everyone to participate in something that is very important and exciting. At the end of January, the Air Force Space Command was tasked to look at modernization of GPS. AF Space Command is putting together a Capstone Requirements Document.

The Department of Defense (DOD) recognizes the importance of civil input into this process. The DOT will be the funnel of all civil input and will include the DOT POS/NAV and the IGEB. In parallel, the GPS JPO will put together an Acquisition Plan. The civil community has the opportunity to participate. A working group will gather the data from the entire civil community and evaluate whether it's justifiable and obtainable. The Air Force has a process in place, which the civil side needs to parallel.

As documentation becomes available, it will be on the NIS bulletin board, along with other sources. Hopefully, the International Subcommittee, the timing people, and the GPS Industry Councils will provide input. The request for input will also be distributed through the Federal Register and the Commerce Business Daily. Secondly, they are considering holding seminars to provide a forum for input.

The Air Force schedule is very aggressive schedule, looking at the type of requirements, the operational performance base requirements, and the position management plan. The schedule is:

17 April- 1st draft CRD
16 May- 2nd Draft CRD
1 July- 3rd draft CRD

The Acquisition Management Plan will be a road map document which will feed some other thing. It is a challenge for all of us, whether government or private, whether casual user or a user involved with safety uses.

When the military took a stab at the civil list it included increased accuracy, integrity, total availability, and stable stewardship. The civil community needs to think beyond just asking for more. There are operational procedures and capabilities, additional signal formats while keeping in mind that there are a lot of receivers the cannot be made obsolete. Remember, GPS is more than satellites. There are improvement to ground segment operations and user equipment.

The Coast Guard Web Page will be the vehicle to gather CGSIC input. Actively solicit input from others.

Questions:

Bernald Smith stated he represented SAI which is about 500,000 pilots world wide, most of whom are international, and the process needs to solicit more international input**.**

Answer:
The State Department will also be active in the outreach. The International Information Subcommittee will also be involved. They do not intend to ignore the international user.

CAPT Lapine said the GIAC is also behind this activity and will be willing to take input to make sure everybody gets heard.

George Preiss asked if they were talking about something that might be called GPS Block III.

Answer:
The term GPS III can be misleading, because is a long term effort that looks at the near and long term, so it can be more than just a Block III GPS.

Mr. Preiss added that after sending out the L5 question to over 2000 addresses, he saw 17 replies. The rest of the world wonders if the U.S. is really asking them and will have to push to get realistic input from the rest of the world.

Mr. Skalski said he understood the problem. There was also difficulty getting civil input to the GPS operational requirements.

Dave Scull said the schedule is ambitious and he thought more time was needed for the international input. The International Association of Institutes of Navigation will be holding a congress in Amsterdam that would be an appropriate forum for this.

He added that he had been involved with search and rescue in the Virginia area and he sees a need for differential corrections. The GPS receiver was essentially useless because of the accuracy needed to lay out the search pattern. There are ways of providing differential corrections that are fairly economical. Amateur radio has a system called a Amateur Packet Recording System. There are hams already transmitting GPS coordinates on a voluntary basis. The search and rescue emergency services throughout the country should not be ignored.

Answer:

Those requirements need to be captured. The time frame was set by the Air Force, but we must try to do it within that schedule, as difficult as it may be. He will continue to take input after that date.

Mr. Preiss asked if market surveys had been considered.

Answer:
The money was not available within the existing budget to do market surveys.

GPS Interference Reporting
Capt. Dan McGibney, GPS JPO

Capt. McGibney stated Kaysi Rehborn was his replacement. Capt. McGibney's slides are included as Appendix I.

The international community requires a reliable global navigation service. GPS interference reporting provides a means of achieving this reliability through a process of communication between the users and the maintainers of GPS. The user community provides input as to how effectively the system is working, and then the GPS JPO offers a possible explanation to the user for specified incidents. This reporting process has helped to identify areas of persistent, unexplained anomalies. Some of the potential sources of interference may include TV transmitter harmonics, telephone microwave links and relays, and radar sites. The JPO's future plans involve being a catalyst for problematic regions to be investigated, using information for military mission planning, and helping the FAA better tie into this process.

The FAA is supposed to visit the JPO to talk about improving the reporting system. Different agencies and governments need to start working together to share information. To investigate problem regions, countries can get together and work together to analyze the area. A complete picture is not available because insufficient information is available on Asia, South America and Africa. South America is our neighbor, but not one report has been submitted from there. That does not mean there are no problems.

When you encounter a problem, it should be reported to the Coast Guard Navigation Information Service (NIS). Aviation reports should go to the FAA, and when they are received at the NIS and the JPO, they go straight to FAA. When the investigation is complete, the reporter is notified and findings are posted on the NIS Web Page. It is a living process and should adapt to meet the users' needs.

Questions:

Keith McDonald said the reporting system is important and that the aviation community has had a tremendous interest in interference for several years. Two reports were completed recently by RTCA Special Committee 159 on GPS. Working Group Six on interference, chaired by Dr. Steve Heppe, just completed just work. That Report is now being circulated. They looked at sources and possible causes, and almost all of the reports that they found were explainable.

Another useful report is the Special Committee 185 which looks at spectrum plans and spectrum requirements going out to 2010. They are also looking at the interference concern as well as what is protected, including radar.

Sally Frodge, DOT, stated the mobile satellite services are potentially a mobile source of interference. She encouraged everyone to look at the RTCA report on interference which addresses that type of interference to make sure that future problems with mobile satellite services can be addressed. This could be tied into the Capstone Requirements and the search for a technical solution.

GPS Information Needs
Lt. John Radziszewski, Coast Guard Navigation Center

Lt. Radziszewski's slides are included as Appendix J.

Since 1995, the NIS Internet Service has grown. Last month (February 1997) there were over 500,000 hits. Most were GPS related.

The NIS is improving users' information access. There is a real need to coordinate and consolidate a lot of information into one repository. The NIS is the civil interface and is looking at three initiatives. NIS is developing a GPS database with all of its files. The NIS is also implementing a search engine that will allow the user to find a document by entering a text word or string. Thirdly, the E-mail List Server will enhance virtual communication and will help share information over the Internet. It should work well with the type of information this diverse group of users share.

These types of thing are very valuable. The Internet search engine can be used in tandem with the GPS database to retrieve archived information. The NIS will be a one stop shop for all of the information. The Internet will be a great vehicle to allow less time spent finding information.

The E-mail list server is a relativity new technology because of the complexity. You enter the Web Page, subscribe to a list on your topic of interest. All notices on that and related subjects will be automatically sent to you. Members of the list will also be able to send out E-mails to other members of some lists.

GPS information needs change as the systems grow in complexity and as the diversity of users grow. Initially there was a core group of scientists and engineers. Today there is a wide range of users that span all walks of life, have different levels of interests, different user levels, or needs, depending upon the way they utilize GPS.

The Coast Guard Navigation Center is going to be more proactive in evaluating user needs. The first step is to retrieve and document status messages, and things of that nature, more rapidly. The second is to work with the Air Force on status messages, NANUs, etc. to make sure that they are timely and relevant, and that the NIS is providing that information the way it should. He would like to contact CGSIC members to talk about GPS users' needs and how the NIS can enhance what it is already providing.

Questions:

George Preiss asked if there were any intentions at this moment to shut down the bulletin board services in favor of the world wide web. He added that a lot of files are available in PDF format and that some machines cannot handle PDF.

Answer:

There are still about 600 active users of the BBS. It is a low budget item and will run for at least the next year.

[Editor's Note: Since that time, the decision was made to investigate an earlier date terminate the BBS. The announcement was posted on the BBS in May. If sufficient negative response is not heard, BBS operations will cease on 30 September.]

The PDF format is an issue. It is supposed to be an international format. The NIS has a lot of documents and it is easy to scan them, do an OCR check, and put them in a PDF format. He can try to lean away from the PDF and provide information in text, or Microsoft word formats. The NIS is trying to keep pace and needs users feed back.

International GPS service for Geomatics
Gerald Beutler, International GPS Service for Geodynamics

The International GPS Service for Geodynamics (IGS) is an international service which is working under the offices of the International Association of Geodesy (IAG). The international IGS governing board consists of about 15 members. The IGS collects, archives, and distributes GPS observation data, then, within the IGS, these data are used to produce high accuracy GPS satellite ephemerides, earth rotation parameters, coordinates and velocities of IGS tracking sites, GPS satellite and tracking station clock parameters and atmosphere information. The accuracy should always be sufficient to support state of the art scientific purposes. The IGS accomplishes its mission though a network of tracking stations and three global data centers. The analysis centers have generated daily products without interruption since 1992.

The start of the 1992 IGS test campaign took place 21 June, 1992. This test campaign was carried out for three months, and was so successful that it never ended, and continues today. The IGS was established as an official service of the IAG on 1 January, 1994. Today, the IGS consists of the global network of about 80 stations.

There are three global data centers, one at CDIS, one at Institut Geographic National (IGN) in Paris, and one at Scripps Institution of Oceanography in California. There are seven Analysis Centers including the Astronomical Institute in Bern, Switzerland, EMR in Canada, European Space Agency, Germany, Jet Propulsion Laboratory at Pasadena, GFZ in Germany, NGS in Washington and Scripps Institution of Oceanography. The Central Bureau, located at JPL is directed by R. Neilan.

All the stations are processed by at least one analysis center. Some of the stations are processed by three (or more) of the analysis centers. The Central Bureau Information System contains all the essential information about the global service and the official products. It produces the IGS Message and IGS Reports. The Central Bureau Information System is available through the Internet.

IGS makes available all the individual products from the seven IGS centers. An official IGS product, the IGS orbit, is a weighted mean of the individual contributions. The advantage of the IGS official product is not really its position, but its reliability. This combined orbit is available eleven days after observations, to a five cm level of consistency.

There was considerable pressure from the atmospheric community to come out with very rapid products to do better predictions using the GPS. Since 1 January, the six united centers reduced time to produce the rapid product down to 23 hours. This rapid product is also very accurate. There were also attempts to come up with predictions on the level of 30 to 40 cm. Predictions are for 48 hours ahead, but, because of a 24 hour delay in the availability of the rapid orbit, they are only useful for 24 hours.

Surface-sphere has the same effect on both carriers, so you cannot use linear combination to isolate this effect. Surface-sphere has to be modeled by all analysis centers to get down to the millimeter or centimeter level. It was very clear that this information is most valuable to the meteorologists and to the climatologists. The IGS is setting up a mechanism to make surface-sphere parameters, in particular the participle water weight content in the air, available to the community.

The IGS is an international and multi-agency service. Although the IGS is set up as a service, with a goal to facilitate research. There are lots of research activities are going on within the IGS. The IGS products are freely available to the scientific community. This will be always the case. The IGS is open to incorporate with other groups operating permanent networks. One of the important aspects of the IGS was to standardize formats and station augmentation, which is observed by many people today.

Question:

An attendee noted Dr. Beutler did not mention GLONASS.

Answer:

The IGS Governing Board Meeting met last Saturday, and as soon as a sufficient amount of dual frequency equipment is available, they will see GLONASS orbits with comparable accuracy produced by the IGS.

19 March 1997

GPS ACTIVITIES
Session Chair: Sally Frodge, DOT Radionavigation Policy Staff

GPS-GLONASS Interoperability Issues
Gerald Cook, Sequoia Research Corporation

Mr. Cook's entire paper is included as Appendix K.

Sequoia Research Corporation has operated a GPS-GLONASS receiver in support of the FAA since 1992. Data collected is for diagnostic purposes, whether healthy or not. Although the December 1995 GLONASS launch filled the constellation, and provided a spare, a full complement of usable satellites was available less than 40 days during 1996.

In spite of the continuity problems, the ground segment maintained the GLONASS satellites at a high level of accuracy when they were healthy. By monitoring the dispersion of the time transfers between the SRC cesium clock and the GLONASS system clock, as determined by different satellites, it is possible to make estimates of satellite performance. In general the RMS of the error is on the order of 4-5 meters. Actual user range errors, including multipath and receiver noise, are closer to 8 meters.

Individual satellite clock/ephemeris induced errors can be estimated by separating the residuals. There is a very high correlation between the pseudorange errors and the clock upload dispersion.

GLONASS integrity is a problem of concern to navigation users. Because the almanacs have no time stamp, their health information can be in question, especially when satellites disagree. There appears to be some onboard checking, which has improved on later satellites.

The most common GLONASS integrity lapses are message data dropouts. They may occur at any time, with varying duration. Newer satellites are better able to immediately identify themselves as unhealthy when the clock or ephemeris data drop out.

Although GLONASS can be a highly accurate navigation and positioning system, the real-time user must exercise caution to ensure he is getting good information.

Questions:

In response to a question about redundancy, Mr. Cook said he did not have redundancy on his receiver. He was able to double check and make some sanity checks for the clock failure that occurred. It was listed on the Internet as being a problem at that point.

Keith McDonald said it was also 1/3 of a second or 1/2 of a second rotation on the PZ 90 that did the WGS84. He also thought it was longitudinal displacement of the z-axis specifically for about 2-4 meters.

Answer:

It could not be determined based on one station, but it was 2-3 meters z displacement. The data fits were good. More collection sites are needed to do a world wide transformation.

Keith McDonald then asked how he determined the errors from uploads.

Answer:

The data was compared with the latest assessment of the clock bias with the predict from a day ago. A part of that has do with unpredictable clock error growth. The best estimate is for today and yesterday. Projection is an assumed error.

Rolf Johannessen commented that Mr. Cook tried to present a balanced picture of the strengths and weaknesses of GLONASS. In addition, to sustain confidence in GPS, information must be maintained and improved.

USCG Differential GPS Update
Gary Schenk, USCG Navigation Center

LCDR Schenk's viewgraphs are included as Appendix L.

Currently 53 sites are providing differential signals; Key West is a new addition and one of the best performers. The Coast Guard is working with the Federal Railroad Administration to install a site in south central Washington which should be operating by the end of April 1997. The US Army Corps of Engineers is working to complete three more sites; near Omaha, Louisville, and along the C&D Canal in Maryland. These Corps sites are expected to be running by the end 1997.

The Coast Guard expedited the IOC phase of operations in January 1996 using a lot of existing radiobeacon equipment. Since then, a lot was learned about the equipment and the susceptibility of the sites to external factors such as storms, hurricanes.

These signals comply with the latest international standards and the RTCM SC-104 format. If users have healthy DGPS signals, they are accurate and have full integrity.

There are four specifications to meet Full Operational Capability (FOC): accuracy integrity, coverage, and availability. Currently the first two are met. The system consistently provides better than ten meter accuracy; 49 provide roughly one meter accuracy with a SD of better than 1 meter at the source. The system has strong integrity algorithms on which navigators can rely.

The Coast Guard is currently using helicopters to gather data to determine the extent of each beacon's coverage. Operational results indicate the system design will allow it to meet the 99.7% signal availability requirement. This requirement is not currently being met at all sites, but a current effort to upgrade the system equipment will meet this goal.

The transmitter replacement project is proceeding well, with a contract expected in a few months. These transmitters will have battery backup, capable of sustaining operations for about 22 hours during power failures. Some failure prone antennas will be replaced. Replacement might cause some minimal service disruption.

15% of coverage verification is completed, concentrating on suspect problem areas. Two coverage gaps are already identified. One gap in SE Alaska which will probably require two sites to cover. A second gap in SE Puerto Rico and the Virgin Islands where one site should fill the gap. If any other coverage gaps are found, they will either upgrade nearby sites or add new ones to provide the necessary coverage. Site certifications and risk assessments need to completed. This work should be done in Oct 1998.

Questions:

A question was asked about the coordination between the U.S. and Canada for the Great lakes and the coastal areas.

Answer:

They are still in negotiations and do not have a formal agreement to coordinate U.S. DGPS services with Canada right now. They want to coordinate the notification systems and are working on that.

The broadcast standard specifies that they provide differential services out to 20 miles at sea from shore. It does allow an extension to 50 miles offshore, but there have been no recent moves for that.

George Preiss asked for more information on site certification.

Answer:

They review that the system is installed properly and the ground is connected, and the pieces of equipment are connected correctly and interact properly. During testing, they have had a number of failures, so site certification is useful.

Rolf Johannessen asked LCDR Schenk to explain how a standard duration of one meter is achievable when GPS is WGS84 and the charts are NAD83..

Answer:

The Coast Guard provides a navigation service and that navigation is based on NAD83 information. But, by adjusting the data and by getting the positioning of the reference station antenna in a NAD83, they are now essentially providing corrections in NAD83 format.

Bill Strange added that, in the U.S., the difference between WGS84 and NAD83 is between one-half and two meters. All the charts and maps are in the NAD83, so you need your Navigation system to be the same as your chart and maps.

Karen Van Dyke asked LCDR Schenk to comment on what the helicopter flight found, comparing measured coverage against predicted.

LCDR Schenk said their modeling program, called COAST, is a coverage analysis estimation. So far, much of the results follow the predicts. In one case where it didn't meet the coverage flights, they went back and did a little figuring and realize that the technician used the wrong beacon signal strength at that beacon.

In Alaska, the coverage estimation program did not perform as well. In southeast Alaska There is a large coverage gap, that is being researched. One thing suspect is that the terrain in southeast Alaska is quite vertical. They will have to come up with an adjustment factor and determine what power is needed to correct that.

Dave Scull asked what differential will cost for land users.

Mike Swiek answered that, right now, $500 to $2000 is the range for the differential add on for DGPS.

Keith McDonald said the Coast Guard has done just a magnificent job in implementing its service on a small budget. The WAAS at last count was on the order of $600M to $700M. The concern is that the WAAS may come in 1998 or 1999 to give five to seven meters in the vertical and three to five meters horizontal throughout the North America continent. What kind of coordination has there been between the Coast Guard System and the FAA, because some might feel that they are possibly redundant. They both perform a very useful service.

Joe Canny responded that about three years ago, a fairly extensive study of augmentation system requirements was conducted for the full range of transportation users. Sally Frodge was one of the principal investigators. They concluded at that time that it appeared that the extension of the Coast Guard DGPS system to get nationwide coverage, plus the FAA WAAS system as then designed, would together meet the full set of user requirements. That took into account a variety of technical differences and a variety of different user needs.

As the architecture of the WAAS evolves and as the development of the Coast Guard DGPS system reaches the operational stage, there might be a need to revisit those questions. It may be time to get the WAAS system designers along with the Coast Guard and others together to see whether those conclusion are still valid.

Nationwide Differential Expansion
LCDR Len Allen, Coast Guard Representative at OST/P-7

There are a lot of users that would benefit from a nationwide DGPS system. A lot of federal, state and local agencies were developing individual DGPS systems at the same time the Coast Guard was developing its system. This type of implementation is very expensive and not very efficient. GAO recognized this in September 1994 when they suggested that the government cooperate more among the agencies in implementing DGPS systems. This was echoed in the Augmentation Report to the Secretary of Transportation in December of 1994.

The Augmentation Report recommended that DOT plan, install, operate, and maintain a nationwide system, modeled after the Coast Guard's DGPS system. The Presidential Decision Directive says that DOT will serve as the lead agency for all federal civil GPS matters. It will develop and implement U.S. augmentations for transportation applications. DOT will promote the commercial application of GPS technology and the acceptance of GPS and government augmentations as standards in domestic and international transportation systems, and finally it directs DOT to coordinate U.S. government provided GPS civil augmentation systems to minimize cost and duplication of effort. The recommendations were similar to those made by the GAO and the Augmentation Study.

In January 1997, a team was assembled to develop the DGPS Policy and Implementation Plan. The Executive

Steering Group provides guidance and oversight. The Policy and Implementation Team will define requirements, develop a cost benefit analysis, recommend funding sources, draft a report to the Executive Steering Group, and finally, draft a Policy and Implementation Plan.

Many of the DGPS requirements were addressed in the Augmentation Study. The team is revalidating those requirements and identifying any new requirements.

The Federal Railroad Administration is exploring the use of DGPS in Positive Train Control. DGPS will provide the accuracy and integrity needed to prevent collision, avoid over-speeding derailments, and increase the capacity of the rail lines. (See Richard Shamberger's presentation, also in this session.) DGPS use in Positive Train Control will be tested in May 97 in the Northwest. If this test is successful, and the Executive Steering Group approves, then the DGPS system will expand to cover the entire United States. The nationwide DGPS system will prevent accidents in the rail system, saving over $35M per year. It will reduce fuel consumption by better pacing trains, and increase the capacity of the lines through closer train spacing, thus reducing the need for new infrastructure.

The final nationwide DGPS system will be compatible with the existing Coast Guard system, will be integrated into the Coast Guard system for monitoring purposes, and will provide an accuracy of between one and five meters. Individual DGPS systems are currently used in the Intelligent Transportation System for fleet management purposes. The automated vehicle location system will be used to track truck fleets, police cars, ambulances, buses, trains, etc.

One of the user applications is a wayside information system, which gives you real time graphic information on transit assets. For example, it lets you know if your bus is on schedule and where it is.

DGPS will become part of the integrated vehicle safety system. DGPS combined with map-matching, and communication links, will allow the automatic notification of emergency personnel when an air bag is deployed. So, when there is an accident, it sends a signal to a DGPS receiver, the DGPS receiver sends a message to a transmitter, whether that be cellular telephone or another communications link. That information goes to a local, or centralized command post, which would then dispatch the emergency vehicles to the exact location. This can save some of the 41,000 people who die on U.S. roads each year. This system will also automatically reroute traffic around an accident scene, thus preventing multi-car pileups and improve traffic flow efficiency. The last thing that the system could do is to plot cost-effective trips, thus saving time and fuel.

The information from the augmentation study is being revalidated. The EPA has a requirement to locate 1.4 million toxic waste sites. The National Park Service has a requirement for search and rescue, to locate fire-fighting equipment and personnel, and to identify the location of oil spills. The Department of Energy has a requirement to continuously monitor the shipment of radioactive materials. Department of Agriculture has a requirement for DGPS and their constituency has a requirement for DGPS for precise farming and to monitor and control infestations. The Bureau of Land Management maps natural resources and tracks firefighting equipment.

States have uses for the Coast Guard's differential system and would like to see it expanded. Their uses include mapping the transportation infrastructure, light poles, pot holes, bridges and individual houses. If they know exactly where a house is, when they get a 911 call and the police officer or if the ambulance is equipped with the DGPS receiver, they can automatically be routed to the scene, without looking at a map or a road sign. So, police, firefighters, and ambulances can respond more quickly and accurately to emergency calls. In the north, they could use DGPS to locate fire hydrants buried in snow banks.

The Air Force plans to decommission its Ground Wave Emergency Network System in December of 1998. This system broadcasts at 150 kHz using 300 foot towers. Plans are to convert some of these GWEN sites into DGPS sites. To complete the coverage would require sixteen non-GWEN sites. In addition, four to six additional sites are needed in Alaska. More might be needed depending on the ground conductivity and initial testing. The cost benefit analysis is being done now.

The first phase of the implementation is the proof of concept test in Appleton, Washington, where that GWEN site will be converted into a DGPS site. It will also be used to test the positive train control system. The Memorandum of Understanding between the FRA, the Coast Guard and the Air Force was signed 14 March. Testing will be conducted from April until December of this year.

Phase Two will start if testing is successful and the policy decision is made to move forward with the expansion of the differential system. New sites will be needed to fill in the holes, along with environmental impact statements on those new sites.

In summary, the GAO study, the augmentation study, and the PDD all support a nationwide, Coast Guard-like, differential system. Many federal, state and local agencies have a requirement for DGPS. The PDD directs DOT to lead in the development of augmentation systems.

Questions

Dave Scull stated that the Coast Guard system is low frequency system, GWEN is low frequency. Most of the users in the train control systems and ITS are operating in VHF and UHF. Implementing something in a lower frequency is going to be costly and a waste of existing resources.

LCDR Allen answered the Coast Guard differential system does require two receivers- one to receive the GPS signal and the other one to receive the correction. That would be true no matter what augmentation system was used. Equipment cost should decrease as sales increase. The lower frequency is used to get better coverage. Broadcasting the differential correction over multiple frequencies is not out of the question.

Bill Strange added the applications for this kind of a system, when using it for GIS is much cheaper if you can receive the corrector and get your answer right away, rather than having to process the data. This is a huge savings to buy and operate one receiver and will have an enormous impact. There is no real reason why it can't be a wide area system as well as a local area DGPS.

Mike Savill asked if liability issues had been addressed.

LCDR Allen replied that liability was one of the reasons why the government is looking at developing this system rather than the private sector. He believed there was a statutory regulation in the United States that any maritime navigation system be provided by the government and not by a private provider. He didn't believe that same requirement existed for land use. So, the government is accepting the liability.

Karl Brown, said he represented a lot of land-based users and has provided requirements to a number of studies that have been done by the Department of Transportation. The study on the GWEN sites is logical. A lot of [Federal employees] have positioning requirements and navigation requirements in the real time scenario in the interior of this country. Private industry has stated flatly they won't go to some of those areas. So, it is time to admit that the threat of the government service to private industry is a hollow claim. They are going to go where the pager subscription network exists, where they can sell coverage subscriptions. So it is high time a DGPS system was built in the interior of this country that supports land-based navigation requirements. This is an excellent solution.

Greg Buisson, U.S. Postal Service, added they were very interested in this for some of their uses, and asked what was the deployment schedule to expand the system to the full 38 sites?

LCDR Allen replied if the test is successful, they will look to implement as quickly as possible. The GWEN sites won't be available until December 1998, based on the system being replaced by a space based system. At any rate, the GWEN sites are not necessary in order to proceed. They could start with filling the holes with the non-GWEN sites. But, the time to start would probably be December 1998, with at least two years to complete the installations.

Larry Hothem, U.S. Geological Survey asked if there was a plan in this initial helicopter test, to install in a ground vehicle or in trains to look at the coverage and to make sure that the beacon frequency is the most effective way of transmitting this DGPS correction signal out over land.

LCDR Allen said the plans are to test on rail cars under positive train control. They will probably do some mobile transportation testing in vehicles.

LCDR Schenk said they are holding off on northwest United States flights in Oregon and Washington until the Appleton site comes up. When they do that they will go up the navigable portions of the Snake and Columbia Rivers. The Washington site was selected because of its terrain, for the positive train control system.

Positive Train Control Update
Richard Shamberger, Federal Railway Administration

Mr. Shamberger's slides are included as Appendix N.

Before his departure, Secretary Pena began to talk about an intelligent transportation infrastructure. Not everybody in the U.S. lives within eyesight of water. There is the need there for a differential signal away from water.

There is a relationship and relative growth between railroads and trucks, rivers and canals, which is our navigable waterway situation with the Coast Guard, and also oil pipeline. There will be a capacity management problem one day. There are lines of trucks on the interstates. An intelligent transportation infrastructure might contemplate putting some of the trailers and containers on a train and moving them from coast to coast. The border between Washington and Oregon is the Columbia River Gorge and has 855 miles of railroad. The Columbia River Gorge is deep and winding and will test GPS signals. It might be hard to get a signal in there.

The Seattle to Portland corridor is extremely congested and has been designated as a high-speed passenger corridor. Amtrak coexists and runs over freight owned rails. Before the end of December, some passenger trains will run through there at 100 mph, thus needing positive train separation. Passenger trains operating at a speed of 110 mph, will operate in and amongst freight trains operating at different speeds. Something will have to keep them apart.

The Coast Guard's differential frequencies range between 285 and 325 kilohertz. The railroad uses as its RF telecommunications network, two sets of frequencies- six dual channels in 900 MHz, UHF and 91 channels in VHF at 160 MHz. These locomotives are being equipped with a dual radio that handles both with digital communications.

The rail industry in the U.S. owns its own telecommunications network consisting of 39 UHF or VHF towers. Positive train separation enforcement authority restricts speed which is controlled by computer. Systems enhance mankind's ability to business better.

Central issuance and control of the authorities comes from Mother or Headquarters, either Fort Worth or Omaha. Communication is two ways. There is on-board enforcement on the locomotive. The location determination system is coming from multiple sensors on board the locomotive. Every curve and every switch of the rail has been surveyed down at the centimeter level. Navigation is a one dimensional problem; it is known which track the train is on. Differential GPS gives the locomotive time and 10 to 15 meters of accuracy. The Coast Guard system is just a perfect fit. It is not good enough to say, that's what track I am on. Remember, railroads have parallel tracks. Not quite good enough for that, but it is good enough for this interactive breaking computation. What is a locomotive doing with all this information? This is a sensor sweep. On board the locomotive. There is a tachometer, there is a digital gyro, a ring laser gyro, and it is also calculating, you know when you go into a curve, you bank a little? The gyro is looking at the curve, it is looking at the super-elevation, it is looking at the curve and finding itself on the curve, even though there is no switch. The GPS is flying along with all of this, it is a track data base. All of this feeding into a common tracker, which we are all familiar with, this is a redundant system. This system will stop trains, but the railroad is worried that it might stop the train unnecessarily. So, they called for no more than one false breaking per million train miles. On the Union Pacific railroad, there is one million train miles accumulated on a daily basis. In other words, one false alarm, that is all they want to put up with. They do not want to put up with a loss in productivity.

The Air Force was going to decommission and surplus the Ground Wave Emergency Network (GWEN) in 1998 at a cost of $300,000 per site. The tower at Appleton was transferred by Memorandum of Agreement, last Friday, to lend the Appleton site to the United States Coast Guard and Federal Railroad Administration to emulate a Coast Guard differential system.

Some of the Coast Guard towers are not very good. The 300 feet GWEN towers can withstand hurricanes. It is a 30% efficient antenna, with twelve guide wires off the top, and the first 60 feet are antenna. The GWEN sites are on 11 acres with a tremendous ground plane, EMP hardened shacks, and back up batteries. It can be turned into a Coast Guard differential station. It will run at 300 kilocycles, 300 watts.

The terrain includes the Cascade Mountains, the Columbia River gorge, and forest canopy. The Coast Guard is using helicopters to pick up field intensity on navigable waterways, which would include the Pacific Ocean, the Columbia River, and the Snake River.

The tests start in May. They will test signal reception. There are a couple of GPS blind spots on the western slopes of the Cascades where the accelerometer and the digital gyro are used until the locomotive gets to a switch, and reregisters.

The Columbia River Gorge is a proof of concept. It uses Differential GPS, and other sensor input. It is an electronically enhanced locomotive, and if it works in this nation, it will work anywhere in the world.

Questions:

Bill Strange asked if the proof of concept works, will the Appleton station stay on line?

Answer:
Yes.

Jerry Bradley asked about the integrity, continuity, and accuracy requirements for the differential GPS.

Answer
The accuracy and integrity are the same numbers that the U.S. Coast Guard quotes to everybody else. The backup systems support the 99.999% requirements. One of the things the Kalman filter does is take a look at the entire sensor sweep, and if it doesn't like what it sees coming off of DGPS, that gain goes down 5% and one of the other gains goes up. The real integrity requirement on the differential GPS for Positive Train Control is in the FRP.

GLONASS enhanced GPS could probably could come down to 13 meters. Switches are farther apart than that. Then no differential would be needed. WAAS might also be an option.

International Activities
Session Chair: George Preiss, IISC Chair

Status of International Agreements
Henry Baird, Department of State

Mr. Baird's slides are included as Appendix O.

Mr. Baird said he had been on two of those consultations: one with Japan and one with the European Union in Brussels, Belgium. They are currently working on only one agreement. There might not be an agreement with Russia; that is still to be determined.

The Presidential Decision Directive directs the State Department to talk to other countries and to decide if bilateral or multilateral agreements should be made with those countries. The international agreements on GPS with Japan and the European Union (European Union or the member states) are both feasible, and probably desirable.

There was a lot of support from the Japanese. It was probably the first time, in Japan, that all the groups have gotten together that have something to do with GPS. Groups from the Ministry of Foreign Affairs, transport industry, trade communications, Ministry of Construction, and the police, including the national police, and the Japan Defense Agency. They have formed their own interagency group, very much like the IGEB. Japan will send a team to Washington in April.

The full range of issues discussed in all three places is:

- GPS Policy (and where we are going with GPS for the foreseeable future),
- transportation aspects,
- mutual security, defense aspects, and
- the commercial aspects.

There are a lot of subdivisions underneath those. Because Russia has its own system, the discussions with Russia were a bit different.

Dr. Erdminger, Directorate General of the Transport Directorate for the European Commission, led that delegation. There were also people from ESA, Eurocontrol, other Directorate Generals, industry, telecommunications and the member states. Most of the member states were represented. NATO was also represented. The Europeans are eager to continue discussions and look at some sort of written agreement. A list of issues came out of that discussion. Both parties need to look at the issues and prepare for further talks. The discussion in Europe were mostly about a global navigation satellite system.

Russian talks included the Ministry of Defense, Transport, Russian Space Agency, and some defense industries. Their interest was along the lines of technical issues. The U.S. delegation attempted to get some more information about the health of the GLONASS Constellation and sustainment, but didn't get a lot of information. But, the main point was to get that discussion channel open, with everybody that is involved in GPS on both sides.

The Russian delegation proposed an ICAO working group to discuss issues with GPS and GLONASS. Both groups want to continue working that. Russia also proposed coordinating benchmark points in the U.S. for both using GPS and GLONASS for Category I, II, and III landings, joint certification of GPS/GLONASS equipment for marine navigation, and a single information service for international users, and to look at preventing hostile use of GPS and GLONASS.

The Russians were also interested in continuing discussions with the U.S. on the technical aspects and compatibility between the two systems and commercial use. At every meeting Commerce starts talking about commercial aspects and $8B by the year 2000, which gets everybody's attention. The Russians have also proposed language for the GCC noting the first round of talks and possibly establishing a working group to identify specific areas of cooperation.

The theme at the conclusion of each of these discussions, was to establish some sort of working group. The new TransAtlantic Agenda (December 1995) also calls for that working group to establish discussions for a global navigation satellite system.

Questions:

Bernald Smith asked Mr. Baird to explain the TransAtlantic Agenda.

Mr. Baird:
There is an action plan for the new TransAtlantic Agenda with Europe and the United States to look at a lot of broad areas. It is a cooperative effort between the two regions in order to foster work in lots of different areas. GPS and the global navigation satellite system is just one small part of that. The only thing it says is to establish a working group to look at that cooperation and a global navigation satellite system. The next step, is to get the European group to the U.S.

The U.S./Russia talks might be pushed back into the December time frame. The U.S./Japan talks should happen in April. Then the EU delegation will probably come in June. They are still trying to get consensus among the United States organizations, that agreements are something that we want to have.

An overall frame work agreement, concerning GPS, should not interfere with things that have been going on for a decade. They shouldn't interfere with the FAA or Highways, but should provide some structure to promote work between the U.S. and other countries in dealing with in GPS.

Mr. Baird was asked if there was any discussion with Japan and the European Union about GLONASS.

Answer:

GLONASS is the other global navigation satellite system and will always come up. These kind of discussions are at a very high level and there is always discussion about how it is going to be incorporated into the global navigation satellite system.

Dr. Zielinski asked what was the solution proposed for countries which were not part of the talks and that are outside the European Union?

Answer:
So far, in Europe, they have talked only to countries in the European Union, and represented by the European Commission. He supposed they would end up having to look at bilateral agreements with countries outside the European Union. It is mainly an ease of discussion, where the European Union has been designated from the member states as the point of contact to do these discussions. Otherwise, this whole delegation would have to go to each of the countries' capitals.

This is very preliminary; the Presidential Decision Directive was only signed March of last year. They are starting with the big ones.

George Preiss asked Mr. Baird if there a time frame for the discussions, when they expect to sign agreements and what the contents of these agreements are likely to be?

Answer:
It should happen sooner rather than later simply because policy is not ahead of where the commercial world is and they are trying to catch up. The FAA is making agreements. Something is needed to provide the framework for that, that won't interfere with ongoing discussions.

International Information SubCommittee Frankfurt Meeting
Georg Weber, IISC Vice-Chair

Dr. Weber arranged the meeting which was held in Frankfurt 4-5 December 1996, which was the Fifth subcommittee meeting in Europe. The meeting held was hosted by the Institute for the German Geodetic Institute (IfAG), so there was more input from the geodetic community of GPS users than we usually have.

There were five sessions: policy, infrastructure, practicalities, and plans for the future. Attendees came from many different countries including the UK, Belgium, Austria, Sweden, Denmark, Japan, Czech Republic, the Netherlands, Poland, France, Spain, Switzerland, Germany and a strong delegation from the United States. Many different kinds of GPS applications from land navigation to aviation and maritime users were well covered.

Since this was a European meeting, a lot of people were very interested to see what the connection between the GPS system, GLONASS and GNSS 1 and GNSS 2 and there were a couple of contributions dealing with this issue. Unfortunately, no one from the European Union attended the meeting, but they provided presentation which was given at the meeting. It was a good opportunity to bring people from all over Europe together to talk about GPS. It also gave European users a chance to meet some of the people running the system, which means gaining more confidence in the usage of the system.

A television team who made a video and showed it on the television. It was not scientific, but was on a very low level, and was shown about 8:00 p.m. It was a little bit funny mainly dealing with the possibility of doing car navigation with the GPS system. There was an interview with Joe Canny, one with George Preiss, and a few words with by Georg Weber. It was interesting and good public relations GPS and for IfAG and its activities in Germany.

Country Reports

George Preiss said instituted a more structured way to present national reports using a standardized list of paragraph headings. That system will go into standard operating procedures.

Sweden
Martin Lidberg, National Land Survey

Mr. Lidberg's full report is included as Appendix P.

The DGPS service of the National Maritime Administration is operational since 1 May 1996. The network consists of seven stations and the GPS corrections are transmitted via radiobeacons. The Swedish Civil Aviation Administration participates in the North European CNS/ATM applications project and in the North European ADS-B network. The main objectives are to develop, evaluate, and demonstrate new technologies for air-to-air and air-to-ground data links, and ground data networks. Their communication device based on self-organized staging technique is also used in the project.

The Swedish network is managed by the National Land Survey in Sweden and it consists of 21 stations. From 12 of these stations, pseudorange corrections are delivered to the EPOS service and broadcasted through the RDS channel on the FM radio network.

Finally, a research project has been formed in collaboration between National Land Survey, Onsala Space Observatory, and Terracom towards real-time phase measurement, using this network and the new data radio channel FM radio network.

Poland
Dr. Janusz Zielinski, Space Research Centre, Polish Academy of Sciences

Dr. Zielinski's full report is included as Appendix Q.

There is an establishment of the reference frame for any application of GPS, navigation, mapping, etc. is connected with the European Project, EUREF. It is stable enough for for surveying applications, but is also compatible with WGS 84 for any navigational military application.

In the first stage, Poland made the first comparisons in 1992 when it established that zero-order network which connected to a number of points on the territory of Poland belonging to the European network. The next stage was finished this year, which was the densification of this zero order POLREF network. This very precise network of 359 points covers the whole territory of Poland and is supposed to coincide with the old triangulation network, thus having the possibility to compare the traditional geodetic network with this new one.

There are 348 new points and eleven EUREF-POL stations. There are pairs of points because each station consists of two points- one is located on the old triangulation point and the second one is selected for a GPS observation, or vise versa. Either the first or second point was used as a connection point. The comparing was done in 1994 and '95 in three stages. Data processing took around one year.

The new geodetic reference frame POLREF was established in Poland with precision better than 1 cm.

POLREF is compatible with WGS-84 and is part of the EUREF network.

Questions:

Jerry Bradley asked if he got the same results in the vertical dimension.

Answer:
No, the vertical is a little bit less accurate, by a factor of one to three.

Czech Republic
Dr. Frantisek Vezrazka, Czech Technical University of Prague

Dr. Vezrazka's paper and slides are included as Appendix R.

The Czech Republic is engaged in digital signal processing in DGPS. They have developed several types of GPS receivers, including combined GPS/GLONASS receivers. They have taken great pains to establish differential satellite navigation services in the Czech Republic.

First, they constructed the GPS reference station at the Czech University. Corrections generated by the reference station are transferred by the microwave link to the Prague TV tower. They are coded into the RDS signal and transmitted via Regina FM radio station in Prague on the frequency 92.6 megacycles to cover the Prague vicinity. Corrections are transmitted in the format that is very close to an NRSC code. We developed a stand-alone module which receives the RDS signal and codes them into RTCM format.

Because of difficulties with the VHF signal propagation in towns and in rural areas, they decided to use a low frequency transmitter for correction dissemination. This transmitter is situated in a small town 50 kilometers east towards Prague called Podebrady. Corrections disseminated by this low frequency transmitter cover the whole of the Czech Republic.

In the near future they are going to disseminate corrections in RTCM relation 2.2 format, meaning differential GLONASS corrections.

Question:

Karl Brown said he was visited last fall by two parties from the Czech national park service. They talked about GIS and GS spatial data. They were unaware that any kind of corrections were available. He asked if their signal got into the woods, and if those park service people contacted Dr. Vezrazka.

Answer:
The problem is coordination of DGPS services in the Czech Republic. Since the '80s each year they have organized seminars on GPS technology. The knowledge of GPS technology is very low and some people are interested in using GPS but are not sure if they should invest in this technology.

France
Pascal Willis, IGM.

Mr. Willis' slides are included as Appendix S.

The National Council for Geographic Information (NCGI) is an interagency advisory group which helps the Administration plan its future by asking the user what it wants for the future. There are technically oriented groups which are in charge of topics including positioning, which are becoming more and more involved with GPS. This static and dynamic group now has more than 80 people working in it. It is a rather informal forum when you get people from administration, private companies, and from research.

For the application the IGA has recomputed its entire geodetic network. Like other European countries, it has a densified user network, so that everybody has access to the geodetic reference for his whole country at the one meter level or better. In France this is a 1,000 point network, precisely leveled using GPS. The next question is, should they stick to the 1,000 points or should they densify to 6,000 points?

The other question is about receivers. Should the receivers be connected to the Internet or to another communication link? There is also a legal problem. GPS is not a French system. If the change is made to another system, they will have to start from the beginning. With GPS, it takes about two years to do the national network.. Without GPS, it used to take about 100 years to do it.

There is a group studying these questions and trying to come up with a good solution, using the existing network that already exists for DGPS. The first goal is to have permanent network of geodetic receivers. They do not transmit their data in the real time. After the experiment they will try to get funding for a global network.

The DGPS activities in France are rather different between the maritime and land-based applications. Lots of options exist for the maritime application. There is a private GPS manufacturer in France which has already three or four stations. Four receivers exist, but without communication, so it is a permanent, but not active network.

Another question is how much accuracy do the users need? The first thing they will do is to find answers to these questions.

Norway
Lars Bockman, Startens Kartvert

Lars Bockman said that there were few changes from the September report. They plan to integrate GLONASS into the system to increase the integrity, especially in the northern latitude areas. The GLONASS inclination is better at northern latitudes, so the research is in that area. Their geodetic reference system is part of the European system. They will work this summer to meet the WGS84 requirement. There will be a better report on that at the next meeting. A tracking integrated system was developed with a Norwegian private firm to assist the user to establish and update a national data base in Norway. And the definition of our data base is running around 50 meters with an accuracy of +/- 2 meter. And this system is using differential GPS from other national service and inertial systems.

Question:

Jerry Bradley wondered how many countries would meet that January '98 date?

Answer:
Most will because the adjustments of the European triangulation has been done, repeatedly and repeatedly and the difference between EUREF and WGS84 is insignificant at the mapping level, similar to the situation of NAD 83 and WGS84.

Canada

Robert Duval, Geodetic Survey of Canada, Department of Natural Resources

Mr. Duval's paper is included as Appendix T.

Canadian active control system, or infrastructure, was established as a modern concept to maintain the Canadian Special Reference System. Canada is a very large country with very little population so it is unthinkable to try to implement continuous tracking stations with the density that is being done in the U.S. So, they will provide positioning accuracies over the Canadian land mass and adjacent region, of less than 1 meter in real time, using the GPSC. That is the real time GPS correction.

Geodetic Survey has been involved with precise computation of satellite orbits, satellite orbit predictions, and orientation parameters, since 1992. This information is contributed to IGS. They have also been computing precise satellite corrections at a 30 second rate. These products have been made available to Canadians to improve their point positioning.

The real time system includes a real time data processing facility, a data distribution point and a monitor station that is a combination of both the collector and the virtual point. The network consists of 16 stations, where eight of those 16 stations are operated in real time to support the GPSC service. Some are configured solely as collector stations. Four additional stations are planned for this year for a total of twelve stations to support this service.

One of the major issues with the real time service is real time communication. Now, the Central Processing Center is located in Ottawa. They do not have the infrastructure to do real time communication to the user. It is their intent to partner with the industry specialists in communications to provide the link to the users.

They used two stations which are independent of the real time network. They are part of their network, but not collected in real time. Over a 13 day period they applied the GPSC correction to the 30 second data over a 24-hour period. The RMS of the difference between the position obtained with GPSC correction and the known position of those stations was, in general, below the 50 cm level in the horizontal and the vertical in general below the 1 meter level.

They will upgrade the system soon with the addition of four tracking stations. There are some modeling improvements and availability enhancement that need to be done to improve the accuracy to the 30 cm level.

The Canadian Coast Guard has 11 stations operational, that are modeled on the U.S. Coast Guard's stations. They plan to install seven new stations in 1997- one additional on the West Coast for a total of four, three additional on the East Coast for a total of eight, and two additional on the St. Lawrence and Great Lakes Seaway for a total of six.

Japan
Mr. Hiroshi Nichiguchi, Japan GPS Industry Council

Mr. Nichiguchi's papers are included as Appendix U.

Last November, they established a new company in order to accommodate DGPS correction data using FM sub-carrier DARC system, with which most of the nation will be able to receive FM sub-carrier signals, except the southern and northern end. The company, Satellite Positioning Information Center (GPeX) is in the private sector, and would be a kind of cost center, which be jointly invested in by the voluntary efforts of 17 member companies within the Japan GPS Council. They hope this service will expand the Japanese GPS consumer markets, especially by increasing Car-navigation products, and perhaps will activate the ITS applications and mobile multimedia industries therefore, in the field like Japanese road conditions and heavy traffic jams.

They continue to assist Japanese policy makers for the technical development of satellite Pos/Nav issues. They are deeply involved in an Experts Working Group within the Japan Space Development Commission, and vocally expressed to the government officials there that Japan should basically accept GPS System and then pay attention to harmonization with the international organizations, taking security and public safety issues into consideration.

Ministries and Agencies in Japan are increasingly looking at the effective uses of the GPS system. As a result, there is cooperating work among governmental agencies, such as a collaboration for RTK link-network between Geographical Survey Institute and the frequency allocation authority in MPT, establishing an association body for the effective uses of RTK technology in offshore civil engineering fields.

United Kingdom
Mike Savill, Northern Lighthouse Board

Mr. Savill's slides are included as Appendix V.

Mr. Savill announced that that a public maritime differential system will be provided by the General Lighthouse Authorities in the U.K. "The shipping industry's public endorsement of our joint initiative enables us to plan ahead by combining the provision of alternated lighthouses, light vessels, and solar pad buoys with the latest technology in ground based and satellite radio navigation. This continues a long tradition of promoting maritime safety and is consistent with developments in the European and international maritime communities. It is intended to have this system in place by the end of 1998." One other point in the press release is that Loran C will be adopted in place of the Decca Navigator System as the land based backup to GPS by the year 2000, depending on the progress of the Northwest European Loran C system. In other words, the U.K. will have a public, unencrypted differential GPS service.

The RIN Satellite Navigation Group has approximately 400 members who promote satellite navigation. They recently adopted new aims and objectives for the group. They intend to organize one workshop per year. They intend to generate information sheets on topical issues as needed which will be posted on the RIN Web Page.

In October,with support from the UK Civil Aviation Authority, they had a meeting to educate the private pilots to better understand GPS and the issues concerning the selection of their equipment in the aircraft. This meeting will be repeated in London in April.

In December, a meeting on the Future of Satellite Navigation and Positioning was held in Edinburgh. The RIN will hold a conference in London in November focusing on Europe's Contribution to the Future. Dr. Terry Moore, from the University of Nottingham is organizing a weekend lesson which takes a group of people away for the weekend to show them how to use a GPS receiver, and how to get the best benefits from it.

Finally, in looking at the future role of the International Information Subcommittee of CGSIC, they feel there is a need to move towards a workshop format. So, representatives from different countries, who work in different fields, will try to reach a consensus on topical subjects and topical issues which are outstanding and require attention.

Ed McGann added Germany or the Netherlands started a test on 7 February where the DGPS integrity messages are distributed on the LORAN signal from the transmitter in Germany. The monitors are in the Netherlands, at the University of Delft, where the signals are extracted, sent up to broadcast and received again down at the University of Delft. This is a real time environment where there are all types of crossing rates. They have gone down 1,000 kilometers into France where it is still working. They think it has some advantages. The interesting thing is that it is sponsored by the LORAN people, because they feel that it is an interesting augmentation to have LORAN running with GPS.

Civil GPS: An Airline Perspective
Jeff Ariens, Continental Airlines

Mr. Ariens' slides are included as Appendix W.

Continental Airlines' first activity with GPS happened in Denver, Colorado in December, 1993. The Continental Commuter Division, Continental Express, started the GPS effort.

Currently, Project Newark is a cooperative effort involving Continental Airlines, the FAA, the Port Authority of New York and New Jersey, Honeywell and Harlinshead. Project Newark is a primary project, implementing the use of a differential ground station to provide precision approach capability at New York's Newark Airport. This is important to Continental, because Newark is Continental's international gateway to Europe, the Caribbean, and Latin America.

It is a very big market, representing 60 million customers and is becoming more and more congested. The air space in the area includes Kennedy and La Guardia as well as other airports in New Jersey. The runway configuration is not ideal either. The parallel runways, 4 left and 4 right, 22 left and 22 right, are only 900 feet apart, which prevents the traditional means of parallel approaches. Also, it converges with the crossing runway 11-29 so that adds complications during instrument conditions. The space is not there to construct an additional runway.

Technology must be the means to address some of the capacity issues, to reduce delays and to keep Newark an efficient operation. Differential GPS is particularly attractive because it allows a little more creativity for precision approaches. There are about half a dozen different tools that we are looking at providing. In the straight approach to runway 22 left, and the aircraft coming in from the north would have a cleared approach into runway 29. Right now, there is no precision approach to runway 29 because skyscrapers are in the way of the approach. The curved approach and staggering the aircraft to arrive at separate times will double capacity. In theory, a percentage gain in the arrivals will equate to a lot of dollars in savings to Continental as well as a lot of other airlines. They are also looking at a similar procedure, coming up from the south.

Differential GPS advantages include curved arrivals which shorten the downwind sequencing. With adding the differential GPS procedures, they can locate the converging approaches with the CRDA type, forecasting of the arrivals, allowing a second arrival stream or an increased percentage of arrivals.

This is the certification process and it looks somewhat complicated and I guess it really is. We have spent a significant amount of time going through this and we are getting there They have four separate efforts. There is an effort on the airborne side that involves supplemental type certifications and the certification of the equipment that is installed on the aircraft. There is a ground station development and certification that would certify the MODAVS. The procedures development defines the procedures that this equipment would provide and offer. Finally, the operational side would allow an air carrier like Continental to be certified to use the equipment and the procedures in revenue operations. They are looking at all these issues simultaneously.

They are making some progress. They have a ground station currently installed at Newark that has been transmitting for about six months. The ground station is about the size of a refrigerator and sits in the Terminal C mechanical equipment room. On the roof there are three ISM user, satellite measurement units. It is a full operative design, where you can have any single component fail and stay fully operational with a full backup. It has battery backup capability.

They are RTCA compliant with the CAT I, DO-217 data link which has growth capability to CAT II/CAT III. They are transmitting in the VHF spectrum 112 to 118 MHz, 31.5 Kbps, D8PSK, TDMA message. The receivers are TSO C129 receivers which are basically the same receivers they are using on the airborne side. The software is DO178B, level B compliant, and FAA 8400.11 compliant with certification and operational approval.

Last November they flew a Honeywell Citation with FAA test pilots aboard. The FAA was clearly saying it flew better than any RS they ever flew. They hope to finish their flying trials this summer and to have certification as well as operational approval in the summer.

They have a number of challenges in trying to equip aircraft to take advantage of the technology. They are talking to Boeing to get this capability in their new 737-600s, 700s, and 800s. They plan to equip those aircraft with a multimode receiver that, in addition to the ILS, will have GPS and the differential capability to allow precision approaches using differential GPS.

They see it as the future and think it will make a significant difference in Newark as well as other places. There is also a challenge to retrofit to the existing aircraft. They will work with the Air Traffic Controllers to implement procedures.

Questions:

Karen Van Dyke, Volpe Center asked Mr. Ariens to comment on Continental's dispatch services and how they plan to handle any outages.

Answer:

They had to deal with a lot with these outages when they certified the nonprecision approaches in Aspen. They had two outages a day because there was no augmented GPS. They didn't have the integrity for about 15 minutes a day on both ends of the clock. In that case, their dispatch was on the same integrity algorithm as the receiver on the aircraft, factored in the known satellite outages, came up with any integrity holes that might be there. With the differential ground station, they don't expect any holes and 100% coverage. Also, the oceanic and enroute operations are 100 percent. They run a prediction program for their Guam operation to make sure that the integrity is there and it always has been.

Mike Savill stated Qantas gave a presentation in London where they described the benefits of ADS on specific routes between Los Angeles and Sidney, which resulted in a reduction of 2 hours flying time and significant fuel and cost savings. He asked Mr. Ariens to comment on the Continental position with respect to free flying and their dependent surveillance, and if there are benefits.

Answer:

Continental supports free flight and the concept and thinks there are significant benefits. They have not been as active in the trials as some of the other airlines, but have followed the activity very closely, and see significant benefits.

Growing Pains for the Global Positioning System
Jonathan Epstein, Haight, Gardner, Poor and Havens

Mr. Epstein's complete paper is included as Appendix X.

Mr. Epstein represents maritime and aviation clients who have a very strong interest in GPS legal issues. Initially in looking at liability issues, there was nothing to talk about. That is no longer the case. There have been a number of accidents involving GPS, including: a mid-air collision between two aircraft in Canada, one with the misuse of unapproved GPS in a Medivac flight, and the grounding of the Royal Majesty in 1995.

In April 1995, two commuter aircraft were flying in uncontrolled air space in Canada. In this area of Canada the airway is at least 8 miles wide. The two aircraft collided during daylight. They were both using GPS and so, in effect, they both had the same heading on reciprocal courses. What they postulate is that, because they were both using GPS and presumably using the same positions, they essentially were both flying down the center line of the 8 mile wide corridor.

The Transportation Safety Board of Canada said GPS had effectively narrowed the 8 mile wide corridor to 100 yards, the accuracy of the GPS receivers. They thought that was a major contributing factor to the accident. Now, Transport Canada recommends an offset of one to two miles so that you are off to the side. The Transportation Safety Board recommended mandatory offsets.

The next accident happened in uncontrolled air space in Canada, involving a Medivac flight. In Canada and in Alaska you have VFR certified aircraft that get in a situation where they decide to fly IFR. In this case, it was an Aerospot Helicopter. Neither the pilot nor aircraft were certified for IFR flight. The Medivac helicopter was sent to an accident at a fishing camp. It was near dusk, and the pilot had left in a hurry, without a weather report, and took off at night in poor weather conditions. The Transportation Safety Board of Canada thought he lost his spatial reference while flying at night in low visibility and had a controlled flight into terrain.

One of the issues is that he had been navigating solely with the GPS receiver and without any charts. The Transportation Safety Board's issue was that pilots might think that they can navigate with GPS and without the capability of a fully certificated aircraft. For these types of helicopters to fly in those conditions is apparently dangerous.

As a matter of fact, the misuse of GPS is on the Canadian Transportation Safety Board's Hot List. There are other accidents which involved pilots that have flown below the required minimum altitudes. They postulate that if they didn't have the GPS positioning, they wouldn't be flying that low, with that level of confidence.

The next accident was a 3 year old cruise liner, equipped with an integrated navigation system, including GPS, that fed into an autopilot, and an electronic chart system. The ship was off the coast of New England and had drifted about 17 miles off course, before it ran aground. It had gone off course about 50 minutes after it left port. The GPS receiver antenna had faulted, so apparently there was a loose connection. This older GPS receiver started to send dead reckoning information which was fed into the integrated bridge display. The display had its own check of the navigation system that was based on dead reckoning. It took the same information, compared it to the navigation signal, so it never alerted. The display on the GPS receiver was mounted further back. The GPS also had an audible alarm that could have been hooked up, that wasn't.

The problem was not with the GPS signal, but was in integrating the system. A number of the recommendations from the National Transportation Safety Board investigation had to do with the over reliance of the watch officer on the integrated display. Apparently, this officer and others had been driving the ship based solely on this electronic chart display, to the exclusion of all else. He never sighted this buoy. He had been seeing white and blue water meaning shallows. If the alarm had been set on the depth sounder, it would have alerted, as early as 40 minutes prior to the grounding. So, there are a number of issues that should have alerted him prior to the actual grounding.

Following the accident, NTSB had a conference on integrated bridge systems. A number of issues came out of that conference. One of the big economic values of going to integrated bridge systems is that you can have one watchstander at night. That is something that the U.S. has firmly opposed. Another issue raised was that all these electronic displays interfere with the night vision of the deck officers. Those can be dealt with using cowlings and having the colors of the screens change to red and black at night.

Last week, the NTSB had a meeting on this accident announcing its final report, although the final report won't be published for some time. They did issue an abstract of the probable cause. They called it over-reliance on the integrated automatic features, inadequate training on the integrated bridge system, deficiencies in design and integration of the system, and the failure of watch officer to use other cues. They were concerned not only with the integration issues, but with the watch standing issues as well. This kind of over reliance is somewhat new in the maritime world. In the aviation world pilots rely heavily on their instruments.

In order to get a GPS receiver certified on board an aircraft, not only does the receiver have to be approved, but it has to be approved on that specific installation. This is a costly process, especially for general aviation aircraft. Why do that when you can buy a handheld unit which is unregulated by the FAA, which considers it portable electronic equipment. You do not need to have it certified for VFR. But now, not only are these pilots using this equipment, but GPS manufacturers are marketing handheld equipment to general aviation. In a lawsuit, this puts the manufacturer at some risk.

In the maritime field, another issue is electronic charts. You can blow up the scale of your chart to a level far beyond the actual accuracy of the chart. In fact, approximately 60% of the coastal waters in the United States were surveyed prior to World War II, using older technology. So, you are not getting the level of accuracy that may appear to the user.

In the United States there are 50 different laws, because each state has its own product liability laws. Some states have a strict liability for manufacturers, which means if it is found to unusually dangerous, it doesn't matter whether negligence is proven. This could be a design defect such as the failure of the system to alarm, or a manufacturing defect, or a breach of warranty. The product's liability applies to the whole distribution chain, not just the manufacturer, but the seller and possibly the installer.

For example, a case in New York state was about a 17 year old helicopter that had been sold several times. The third or fourth time it was sold "as is", meaning under no warranties and no guarantees of air worthiness. The company flew it for seven years and then had a problem. The pilot safely auto-rotated the aircraft down, landed safely, although the aircraft couldn't take off. They loaded it on a flatbed truck to take it to be repaired. While on the highway, they hit an overpass, damaging the helicopter. They not only hit it once, they reloaded it and hit another overpass. The owner of the aircraft sued the manufacturer of the Bearcraft engine, saying there was a problem which he thought was related to this 17-year old engine, bought as is. This went all the way to the Court of Appeals, which is the highest court of New York on this issue. The Court of Appeals in New York found against the plaintiff.

A case involving the Coast Guard, it was handed down this year, involving the Coast Guard rescue operation. A sailboat had anchored off the rocky coast in California because his engine had died. The Coast Guard went out to rescue and assessed that he was dragging his anchor and was in danger of going ashore. The boat was rocking violently and the Coast Guard thought the only way to get a tow line to him safely was to have him cut his anchor line so that the sailboat would quit rocking. Unfortunately the man on the sailboat was too weak to pull the tow line on board, so the boat went aground. No one was injured, but the owner of the sailboat sued the Coast Guard. He had radioed his position using his GPS receiver, which is what the Coast Guard responded to, which was very close to the shoreline. He had an expert testify that the GPS position was wrong, he was really much further offshore. The expert's unrefuted testimony was "the GPS position was inaccurate, and though it is designed to be accurate within 100 yards. It is only good for large ships transiting in the open ocean, and can be off by as much as two or three miles." The Coast Guard was found not negligent in that case.

To protect themselves, manufacturers can issue adequate warnings to make sure that issues like integration of systems are dealt with. They should not say you can use a particular piece of equipment for aviation when it is not certified for aviation. Do not make any representations that can not be backed up.

The main issues concerning liability for providers of augmentation are integrity, accuracy, and the alarm capability. The Coast Guard puts out a general disclaimer on their DGPS system that it could go out anytime and that may be effective when discussing government liability. It probably would be effective for a commercial provider to say they provide this service, but don't use it in an aircraft at night, because they can't guarantee that you will have it all the time.

Some products have had problems, both in avionics and on the maritime side, with receiving differential signals. The U.S. government has waived its sovereign immunity in certain circumstances under the federal ports claims act, for claims arising in the United States, and for claims arising on the high seas. They haven't waived the claims arising in foreign countries which poses its own set of interesting questions. What happens if a plane goes down in India as a result of a failure of the GPS system? Although they have this waiver of immunity, it is not absolute and the main way in which it is not absolute is that the government cannot be liable for things that are within the discretionary function of the United States.

The government needs to look at the public's best interest. Liability concerns should definitely not overshadow the public utility of the system itself. The system should never fail. For manufacturers, there are liability risks with any new technology.

Questions:

Bernald Smith said GPS is not going to make dumb people smart, no more than the radiobeacons, VORs or ILSs have made dumb people smart. What do we do to protect ourselves from the dumb people?

Answer:
From the manufacturer's perspective, you can try to negate your exposure. If you are an augmentation provider, the integrity issues have to be addressed first.

Brian Barker, 2SOPs asked if Mr. Epstein had come across any cases where the satellites themselves were responsible for an accident.

Answer:
He has not found any cases of a failure of the GPS system.

Brian Barker asked about the Air Force liability for someone using a bad satellite.

Answer:
Not as long as the government provides the signal that was agreed to be provided to the users. The advertised accuracy of this system is better than 100 meters. But, just because one satellite was providing an inaccurate signal shouldn't make the government liable. On the other hand, an accident victim whose plane has crashed might bring a suit against the United States. They probably wouldn't succeed.

Dee Ann Divis asked if there are changes in the system in the future, and people have a lot of money invested in equipment, are there any issues generated by those changes? There is a ruling today that you can sue the government if they make you change, in regard to endangered species. If the government does something that costs money, you can sue.

Answer:
Mr. Epstein said he would have to look at that carefully. Generally, if the government imposes a regulation that changes your cost, you are out of luck, unless they physically take your land, or the value of your land.

International Information Subcommittee Open Discussion

Australian Meeting
Mike Savill, Secretary, IISC

AUSLIG will host the first Pacific rim meeting of the IISC 25-27 June in Canberra, Australia. The meeting will be three days and include one day of tours, including a maritime differential reference station and transmission equipment. There is also a GNSS Implementation Team (GIT) meeting. The purpose of the GIT meeting is for the Australian government, the civil users, and Australian industry to determine their approach to GNSS implementation. The IISC representatives can attend the Australian GIT meeting as observers.

Warsaw Meeting
Janusz Zielinski, Polish Academy of Sciences

The next European IISC meeting will be held in Warsaw on 11-12 December with technical tours on the 13^{th}.

Mr. Preiss added that starting with the Warsaw meeting, there will be a nominal fee of $50.00 to cover coffee, printing of proceedings, etc.

Subcommittee Business
Mike Savill

There is a need to review the aims and objectives of the International Subcommittee. They need to build the base of the Subcommittee, so that it becomes more representative of the international community. They are not necessarily talking about having a government type of approach, there ought to be an attempt to build in its base such organizations as the International Association of Institutes of Navigation, perhaps the European Groups of Institutes of Navigation and the International Navigation Association. The Subcommittee is setting up a small task force to examine the needs of this Subcommittee and determine how to tailor it to better meet the needs of the international community and also how to better serve the purposes of the Civil GPS Service Interface Committee. This task force will be linked to the Performance Task Force.

Standardization
Larry Hothem

Last year, Henry Toms gave a presentation about the Institute of International Standards Organization Technical Committee 211 on Geographic Information Geomatics. In this activity, there are 20 working items, five working groups carrying all those activities on these various items. Two of the items are directly related and of our interest to the CGSIC and, in particular, in application of GPS or in integrated systems. One group is on the definition of reference systems, that would become an ISO document. There was a lot of concern and discussion if there misuse is of the definitions and relationships of WGS84 and ITIF, etc.

The second group is dealing with positioning services. In position services, the focus is on the standardization of the formats for the interface between positioning systems. They are taking the NMEA 0183 as well as some other formats to arrive at a standard that is complete. It would become an ISO standard. There are provisions for the integrity issue as to the quality of the information. Last week the working group met for four days. The next meeting where there will be held in Stockholm, in the middle of July, either before or after the International Cartographic Association meetings. The draft version is available on the Website and everyone affected should reviewed it and provide comments. It will be very important to industry and to the user community.

Thursday, 20 March

TIMING SESSION
Session Chair: Dr. Wlodek Lewandowski, Timing Subcommittee Chair

Dr. Lewandowski, current Chair of the Timing Subcommittee, recalled the great contributions the previous Chair, David Allan, made to the CGSIC. Next, he described briefly the work of the subcommittee which serves mainly the needs of the international time metrology community, but also the needs of telecommunication timing networks and other users.

Overview of High Accuracy Timing Applications
Dr. W. Lewandowski, BIPM

Dr. Lewandowski presented an overview of the most recent studies on satellite time transfer. He underlined the development of the dual system GPS/GLONASS time receivers. He also reported about some differences between the two systems and possible solutions to resolve these problems. The 13th Meeting of the Consultative Committee for the Definition of the Second (CCDS) was held on 12-13 March 1996 and issued Recommendation S4 (1996), which specified a basis for harmonizing GPS and GLONASS. This recommendation does not make GLONASS depend on GPS, or GPS on GLONASS, but requires that both systems maintain their time and space references in agreement with international standards.

GPS already follows international standards closely, 100 ns for time, and 0.1 m for the reference frame. This is not the case for GLONASS. But, last November and January changes were introduced into Russian time scales in order to align them with the international reference time scale UTC. Further changes are expected. This development is a sign of good will and understanding.

Next, Dr. Lewandowski reported on the standardization of GPS and GLONASS time transfer receivers. A common standard format for dual-system receivers was suggested during last December's meeting of the CCDS Sub-group on GPS and GLONASS Time Transfer Standards (CGGTTS). This format was already implemented on some types of GPS/GLONASS receivers. A list of about 10 major timing centers around the world equipped with GLONASS time receivers was presented. At present there are three types of GLONASS time receivers: American 3S Navigation R-100/10, Russian ASN-16-02, and British Spot. There is also on the market one type of GPS/GLONASS time receiver, 3S Navigation R-100/30.

A study of GLONASS common-view time transfer over baselines ranging from 500 km to 11000 km has shown similar performances to the GPS ones. Present uncertainty of GPS and GLONASS one-channel time transfers is several nanoseconds. The use in the near future of multichannel GPS/GLONASS receivers, up to 24 channels for GPS and GLONASS, could bring down this uncertainty to 1 nanosecond or even lower. This will, however, require the use of temperature stabilized antennas.

Dr. Lewandowski also pointed out that the GPS week number roll-over will occur in 1999. Most of GPS time receivers will not be able to deal with this change. The manufacturers of GPS time equipment will have to resolve this problem before this date. Dr. Lewandowski then transmitted a question from David Allan, concerning records of involuntary errors in navigation messages. Access to such records would be of interest for many people. Also he asked Hank Skalski to comment on that during open discussion at the end of the session on GPS interference testing.

GPS Time Synchronization to UTC(USNO)
Francine Vannicola, U.S. Naval Observatory

Ms. Vannicola's slides are included as Appendix Z.

The U.S. Naval Observatory (USNO) is located in Washington, DC and its mission is to determine the positions and motions of celestial bodies, the motion of the Earth, and precise time. It provides the astronomical and timing data required by the Navy and other components of the Department of Defense for navigation, precise positioning, and command and control and communications. The USNO's measure of atomic time, Coordinated Universal Time (UTC) or UTC(USNO), is based on an ensemble of approximately 50 atomic clock devices, 40 Hewlett-Packard (HP) 5071 cesium beam frequency standards and 10 hydrogen masers. The lead USNO reference system or Master Clock, is a hydrogen maser which provides the physical realization of the computed UTC(USNO). The Master Clock generates the USNO time signal to be used as a reference for various timing systems such as GPS, Two Way Satellite Time Transfer (TWSTT), LORAN-C and Omega. The USNO timescale is adjusted for leap seconds.

The GPS timescale or Composite Clock, is based on an ensemble of the operational atomic clocks from each GPS Monitor Station and each Block II/IIA satellite. The GPS timescale is maintained by the GPS Master Control Station (MCS) 2nd Satellite Operations Squadron (2 SOPS) at Falcon AFB Colorado. The GPS timescale is not adjusted for leap seconds.

The USNO is tasked to provide the GPS with a reliable and stable reference to UTC(USNO). This is accomplished using GPS Precise Positioning Service (PPS) timing receivers with a UTC(USNO) reference input. The USNO monitors GPS Time and UTC as transmitted from GPS for each healthy satellite. The GPS Time correction with respect to UTC(USNO), and based on the entire constellation, is determined and provided to the GPS MCS 2 SOPS on a daily basis.

GPS Time is not to deviate from UTC(USNO) by more than one microsecond, and is steered at the rate of +/-1.0E-19 seconds per second squared, or 750 picoseconds per day. GPS Time has remained well within the one microsecond specification, and for the last two years within 50 nanoseconds (ns) of UTC(USNO). UTC can also be obtained from GPS, and meets the PPS specification of 56 ns (95 percent), as stated in ICD-GPS-202 (Dec 96). The SPS specification is 340 ns (95 percent), as stated in the 1994 FRP.

The USNO has an Alternate Master Clock (AMC) facility,located at Falcon AFB, Colorado, which duplicates the

USNO timing operations in Washington, DC. The USNO Time Service Department Home Page can be accessed at http://tycho.usno.navy.mil.

Question:

Dr. Klepzinski said at one time the GPS time scale was based only on the cesium clocks in orbit and on the ground, and asked if that was still true.

Answer:

They are using the rabidiums too.

Report from NIST
Lisa Nelson, Timing Frequency Division, NIST

Ms. Nelson's slides are included as Appendix AA.

There are two different common view receivers, called N10 and N11. N10 is the common view receiver used to compare time with BIPM in France. The second slide is a chart showing from 1991 to February 1997 that the time differences are pretty close between those common view receivers. There seems to be a slight trend every year, in the middle of the year. They do not know if it is due to temperature. They are taking some temperature measurements on their antennas. The data shown is preliminary.

The second slide shows the temperature measurement taken over that 130 days. This is the same NBS10. For NBS11, there were not any temperature controls on the antennas. The NBS10 common view receiver was compared to the NBS08, which had an antenna controlled at about 32°C, starting with day 50409. They didn't see any significant change once they started to control the temperature on the antenna. The Allied 157 is a different kind of receiver, and the antenna on it goes up to about 30°C.

The other problem that we are having is with some of the measurements they have taken on the Oncore receiver. While tracking satellite 15, it had bad data points. They were not sure why it was happening, other people that are doing these kinds of measurements, feel it is an update on the receiver oscillator that gives bad data points. So that is another thing they are investigating.

The NIST Ionospheric Measurement System (NIMS) compares GPS versus the GOES satellite, showing a 1-3 nanosecond accuracy between the two. They are currently building a new front-end for those receivers, hoping to get more accurate data. The graph shows the time difference between the ionospheric measurements for the GPS satellite and the GOES satellites. The data shows noon and midnight, and are 15 minutes averages. They follow each other within 2-3 nanoseconds, so they have pretty close agreement and track each other pretty well.

For the GLONASS work, they are using a GPS/GLONASS 3S receiver capability with their precision time level counter. They are currently having some problems with it suddenly reinitializing itself. They are waiting on some software to fix that problem. The software that they are currently using has fixed some of the problems. It would not track a GPS satellite correctly when it was also tracking a GLONASS satellite. They will not be able to post out their software for actually another couple of weeks, because they are now in the process of remodeling their room.

[Editor's Note: Due to a tape problem, the question/answer period could not be transcribed.]

GPS/GLONASS Time and Frequency Receiver Developments

James Danaher, 3S Navigation

Mr. Danaher's slides are included as Appendix BB.

The 3S Web address is www.3Snavigation.com.

There have been a lot of reports of diurnal and seasonal receiver-delay variations. The amplitude can be in excess of 20 nanoseconds due to temperature changes, both at the antenna and in the RF unit. The basic problem is: In order to protect receivers against interference, it is necessary to have narrow band filters, and filters with sharp cutoffs. Those filters, by their very nature, have delay ripples and a tendency to vary with temperature. And, if you have a long antenna run, it is necessary to have a filter on the preamplifier at the antenna.

They are trying to do absolute time measurements using receivers. They believe it will be necessary to have at least temperature compensation. 3S is developing actual temperature control capability. They need to have the antenna electronics held at a constant temperature. In order to accomplish this, they have developed a temperature stabilized antenna, called TSA-100.

The TSA-100 antenna has two chambers. The outer chamber is cooled and the inner chamber is heated to allow the antenna to operate over an extremely wide range of external temperatures. At this point, they are qualifying the antenna from -20°C to +50°C. The intent is to hold the internal temperature of the electronics and filters to an accuracy of at least .2°C, even though they are accomplishing better than .1°C. The goal, in terms of delay variations, is to eliminate of any variations beyond 2 nanoseconds.

The slides show graph data from four receivers, two have temperature controlled antennas, two do not. They are 13 minute common view time transfers. The various symbols show GLONASS frequencies from transmission frequencies from 1 to 24.

They are doing a much more extensive test with the prototype antennas, testing them over much wider temperature ranges, and verifying the performance. The results look promising.

There has been considerable improvement in the results of long distance common view time and frequency observations. First, they are going to all-in-view observations for the standard 780 second 13-minute common view type transfer. So, the concept is to operate the receivers on the standard schedule, and to observe all satellites that are above the horizon. This is a step-by-step process to increase the number of channels a receiver can accomplish, so all-in-view is the ultimate goal.

The second step, taking measurements at a much faster rate, is extremely important in improving the quality of the observations and improving the results obtained from common view observations. It turns out that averaging over multipath effects is not the optimal way to treat them, so they encourage the users of the common view receivers to go to a higher 15 second data rate. They will build this into the next software on the 3S receivers: The 15 second code and carrier measurements, fit the standard algorithm for the standard CCGS method of 780 seconds, and then express that data in a RINEX format so the standard software packages can be used.

They are pushing towards larger numbers of GLONASS wide band P-code channels in the dual frequency receivers with exciting results. GLONASS has a lot to contribute in ionosphere measurements. The next issue is to obtain precise GLONASS orbits.

They propose that all of the organizations that have the R100 receivers take these 15 second code and carrier measurements and provide this data set to get continuous Northern Hemisphere coverage. 3S is volunteering to collect, process, and redistribute these observations. Those interested should contact 3S.

They think they can get down to a sub-nanosecond level, but will probably require built-in calibrators to get the very highest performance results. With the temperature controlled antenna, the stability of the R-100 Plus (R100 including the GPS option) should be much better than 2 nanoseconds. The measurements, over a long period of time, will be stable to much better than 2 nanoseconds. Formal upgrades now in testing drastically improve the ionosphere measurement quality, that is the dual frequency ionosphere measurement results from the R100 receivers.

Questions:

Franz Van der Kop commented that antenna cables and antenna cable connectors appear to be ignored in the findings. Normally in checking accuracy and performance of the receivers he looks at different cables and different connectors. We have gone to helix and although expensive and not very easy to use, it has provided tremendous improvement in the stability in just monitoring the P-code.

Answer:
They are aware of these problems and have discussed special cables. There are big differences between cables. They observed another phenomenon, that the French built sensory receivers, when the length of actual cables was increased, the ranging of the receiver changed. They discussed this with the manufacturer, but never got an answer.

Pascal Willis, France, asked when the campaign would open, and if they were connected to the International GPS Service.

Answer:
The software should be released within a few weeks. They had not established any formal connection to the International GPS organization, that collects similar data for GPS. They are doing it to inspire trying to raise the state-of-the-art in terms of GLONASS and GPS/ GLONASS observations. They would be very happy to hand it over to anybody that gets a funding source to do it, because they are doing it gratis.

Georg Weber said he strongly supported the idea of having available precise orbits for GLONASS, but before thinking about new structures for doing this, existing structures should be used. They have worldwide network of sites working with GPS. It is quite easy to add a couple of receivers.

Answer:
They are very enthusiastic about supplying receivers to new sites. These receivers are already doing continuous observations, or many of them are doing continuous observations in already established sites, but is more of a proof of concept. But in the long term, he did see this as being merged into the more standard structure that exists for GPS.

Dr. Lewandowski said it would be good for them to submit it to IGS directly. He could even ask advice on how to start this, format, etc.

Rolf Johannessen said he did not think there is anything fundamentally wrong with the BNC connectors, which are used extensively. But, sometimes you can get a nasty shock if you open up the connector to see how it has been assembled. Some people do not know the differences between connectors.

An attendee added that the BNC connectors work very well, but assembly can be a major factor - the proper attachment to the cable. Cables lying on the roof can be punctured, causing problems with moisture. Those factors really need to be considered before the cables are condemned.

Use of GPS in AT&T Timing Network
Hank Cannella, Technology Manager Planner for Synchronization, AT&T

The AT&T telecommunications network is a living, breathing entity, with electronic switches, fiber optic transport, and synchronization for the network, which is the heartbeat of our network. Without synchronization, the network will die.

Prior to the 1980s, they used the Bell System Reference Frequency, the BSRF, which used a triple cesium ensemble, located in Hillsbourgh, Missouri. The signal was sent throughout the nation. They used a technique affectionately referred to as "send and pray", because there was no verification. In the late 1980s they converted to a digital network, so they needed a new architecture.

AT&T was the pioneer of the use of GPS for timing telecommunications networks. They set up a network of 16 primary reference clock locations, 14 in the continental U.S., one in Hawaii, and one in Puerto Rico. From there, they distributed timing on dedicated facilities, to secondary locations that required timing. At that time they added verification, so they are now able to monitor a signal, and can usually correct a problem before it is service-affecting. This worked well, until recently.

AT&T introduced synchronized optical networks (SONET) which will allow new opportunities. It is a new challenge. By the end of the year, they intend to have 40 SONET rings operational, with coast-to-coast connectivity. By the end of 1998 that number will be up to 50 rings. This time it is not for increased accuracy, but for more careful distribution of the synchronization frequency, because SONET payloads cannot carry the timing signal.

AT&T's timing is significantly better than the ANSI and CCIT standards. AT&T is installing local primary reference GPS receivers at every AT&T office. It is a monumental job and will make one large network.

Questions:

Rolf Johannssen asked what would be the consequences if GPS suddenly stopped transmitting and what specification can AT&T tolerate in terms of SA?

Answer:
Selective availability is not an issue because of the way AT&T operates. They work around it. If they lose the GPS signal, they have holdover capability that can keep the network running for a significant period of time. A few days is not a problem, but if GPS goes permanently, it could have very serious repercussions in synchronization and control. But then again, everyone else will suffer also. They do have backup capability for emergencies, for loss of synchronization or timing at certain locations, and disaster recovery plans, which include local clocks..

Ron Roloff said maintaining precise frequency is very easy compared to maintaining precision time. With the effect of SONET, will there be as much need for precision time and time tagging in the future?

Answer:
AT&T is now looking at the use of precise time, but it is not as important. But there possibly will be applications for precise time and they are pursuing that.

George Preiss said AT&T is providing a service that is essential to society at large. All sorts of other things are dependent on communications facilities, Internet, banking, etc. There is a major solar storm occurring in three or four years. How sensitive are they to this?

Answer:
They are looking at every possible contingency and have plans to address them. Mr. Cannella wanted the attendees to feel very

comfortable that they are looking at every possible contingency, developing an architecture, and deploying it.

Sunil Joshi, Bellcore, represents seven regional companies with their own synchronization network and a similar hierarchy. If you lose your primary references, there is an impact. If you take away GPS, absolutely, there is an impact, but the clock will drive the network hierarchy. Some network providers are also using cesium clocks in their network and distributing timing. The impact will be bad, but there is a network hierarchy. All the requirements are in public domain.

WAAS and Time
Dr. Bill Klepczynski, ISI Inc.

There are three areas in which time plays a very important role in WAAS. The first and obvious one is in the way of a navigation problem. The WAAS satellite is a geostationary satellite to augment the GPS system for navigation. A lot of people are not aware of the difference between GPS and UTC. There are 11 seconds of difference now and there will be 12 in June. With the WAAS time, everything will be based on GPS time. There are two other major augmentation systems, the EGNOS system in Europe and the MSAS system in Japan, which will probably be joined together through the GNSS. For coordination purposes, it would be very wise that people understand the differences between GPS time and UTC, so that as data is exchanged between these systems it is all done on the same time base.

A secondary mission of the WAAS is stated as a time distribution system. The core of the WAAS are these four sections: the WAAS Reference Stations (WRS), the WAAS Master Stations, the Geostationary Uplink Stations (GUS), and the Geostationary Satellite, which is sending out a GPS-like signal.

It is a GPS-like signal in that it is on the L1 frequency. The bit rate and the structure are totally different from the GPS navigation message, and that has to be taken into consideration. There are 24 reference stations in the continental United States, Hawaii and Alaska. There are three cesium clocks at each of the reference stations, so there are 72 cesium clocks which will be involved in the WAAS system. The BIPM has access to data from these clocks, but they have none of the clocks under their direct control.

There will be a difference between WAAS network time and GPS time, because WAAS network time will be the time which is kept at the geostationary uplink station, which will be steered to GPS time, and will be an approximation to GPS time.

In addition there is a correction process. There are two correction processors. The system is extremely redundant and robust. The user here receives signals from the WAAS and the GPS satellites. The geostationary supplements GPS by acting as an extra GPS satellite if you have the receiver which receives the right bit rate and can decode the messages. So, if there are only three GPS satellites in view, the GEO could act as a fourth satellite. In addition, the data which is transmitted by the GEO can be used to supplement, to give you better accuracy and navigation position.

The 24 cesium clocks in each reference station will be the formation of WAAS network time. WAAS network time is the average of 24 cesium clocks. At each of those reference stations, one of those three clocks is dedicated as a primary. The master station has algorithms which form WAAS network time. The time scale will be steered to GPS time. Initially, the main goal is to have GPS time to within 50 nanoseconds and to have WAAS net time to be within 50 nanoseconds of GPS time.

There are two software corrections, the slow corrections and the fast corrections. The slow corrections will be done about once an hour to steer WAAS time towards GPS time. Two messages will be generated from the WAAS geostationary satellite. The Type 9 message is the slow correction and SS Type 2 is the fast correction. This time offset is a difference between WAAS net time, which will be coming from the Geostationary satellite, and UTC, as determined at the U.S. Naval Observatory.

There will be a Time Distribution System (TDS) located physically at the Naval Observatory. The Naval Observatory Master Clock will be input to the time distribution receiver, which passes data back to the computer at the Naval Observatory, to be averaged, and put into a computer which will be accessed by the WAAS Master Station. The Master Station then takes this message, which shows the difference between WAAS net time and UTC, passes it to the GUS. The GUS then transmits it to the geostationary satellite. WAAS provides the capability to have time distributed in real time, in a uniform time scale. It will be beneficial especially in the telecommunications area. Once this is operational, you will have hemispheric coverage, because that geostationary satellite will have hemispheric coverage. So, if you receive this signal, you should be able to get really reasonably good time, good to about 20-30 nanoseconds.

Questions:

In response to questions, **Dr. Klepczynski** said it was decided early on that since time plays such a critical role in the implementation of the WAAS, it was made a part of the mission of the WAAS.

WAAS time distribution is a backup to the GPS time, and a totally civilian system. It is sort of half and half, because it does rely on GPS a little bit.

TWSST vs. GPS Common View
Jim DeYoung, U.S. Naval Observatory

GPS common view is one of the most well-known methods of comparing clocks and is cheap, available, and is very important for International Atomic Time Keeping for the laboratories and timing centers to compare their frequency and time offsets of their clocks. In this example, the common views were restricted to elevations at both sides of about 45° to minimize ionosphere contributions and other things. The key numbers for GPS common view for this experiment, using new generation STEL receivers, is about 4.5 nanoseconds rms over about 260 days of operation, which is probably the best that you can ever expect in any timing receiver.

One experiment they are doing is two satellite time transfers at one hour. Previous to this the most often sampled rate was three times per week. It is not a very good sampling rate for real time realization of what the clocks are doing. For frequency use, it may be ideal. It is a time requirement in simple frequency comparisons.

Within the next month they will do some experiments on the advanced communication technology satellite at 20-30 gigahertz for the RF frequencies up to the satellite. They currently use 12 or 14 gigahertz, ten gigahertz higher than the GPS frequencies. That buys you less ionospheric noise. The problem with that satellite is that it uses base-band switching, which will destroy the time delay values.

GPS common view uses a one-way link down to the timing centers. There are very few systematics that affect two-way satellite time transfer, especially at 12 and 14 gigahertz. There is a slight difference between the frequencies that hav some very small amplitude pair-offs because the ionosphere is not perfectly transparent at those frequencies, but that is actually only a couple hundred picoseconds.

Calibration is the most important thing on almost all the applications. If you want to have a reference, and you want to know that your clock is some nanoseconds away from some master clock, calibration of your receiver is important. It is also the same for two-way. They have a mobile station that we can drive anywhere in the U.S. to make measurements that give the calibration number. They have very small dishes that can be shipped easily.

Two-way gives one nanosecond accuracy. Once every hour a data point is fed to Falcon Air Force Base, goes into a Kalman filter application, which then steers the hydrogen masers. There are two hydrogen masers that are steered from a remote clock 2,400 kilometers away. In about 260 days, it is about 760 picoseconds.

GPS common view has been around for a good long time, but clock technology has reached a plateau, where the time transfer methods have actually reached a level limited by the current technology of clocks. For example, with two-way satellite time transfer, they can compare two hydrogen masers without adding very much noise into the measurement system. It is just a very closed system. The carrier phase of the actual GPS frequency transmission is very stable, which can be used to improve your time transfer.

Geodetic carrier phase takes the IGS data to get clock comparisons to about 700 picoseconds. The bottom line is that GPS common view is still globally very good for two way precision users.

Questions:

Mike Savill asked which applications need this type of accuracy.

Answer:

Fundamental physics is one of the major pushes for this type of accuracy. If you think of band width and synchronized networks, you pack more packets into the pipe. You can play games at those very high data rates. The timing centers are interested in it to supply a reference system to the user.

A hypothetical reason for having a true reference to a better accuracy is that the device that overlooks another device must be one magnitude better.

Timing Open Discussion

Hank Skalski said that in order to respond to DOD requests to test in GPS frequencies he needs to know what lengths and frequency of outages the timing applications could sustain. We are talking about the service not being available.

This would be restricted to a particular geographic area within the United States. They are trying to keep it in remote areas as much as possible, but there may be other areas affected.

Rebecca Casswell added that it could also be several days in a row, several hours at the same time. They will probably not knock out service for a complete 24 hour period.

Dr. Lewandowski said they would address this in detail in Kansas City. The telecommunications people should organize themselves to provide a response for Mr. Skalski.

GPS Future Developments
Session Chair: CAPT James Doherty

Block IIF Status
Lt. Col. Al Mosley, GPS Joint Program Office

There have been two revolutionary things that have occurred this century. One is the Internet, and the other is GPS. The military started the Internet movement through Carnegie-Mellon University, and now they don't own it anymore. The military started GPS and the future is yet to come.

The Block IIFs are currently in development. The Block IIR satellites will eventually backfill the II and IIA satellites. They plan to launch the Block IIF satellites starting in 2001; the block IIR satellites will start launching this year. Twenty-four satellites make up the Constellation.

Block IIF is a follow-on to IIR sustainment satellites for a total of 33 satellites. The first delivery happens in April 2001. The contract was signed with Boeing North American on 22 April 1996 at a contract value of $1.3B. This program embraces acquisition reform.

The program office wrote a one-page Statement of Objectives, which the contractor replaced with a Statement of Work. There were a lot of reform issues in the Request for Proposal. The first vehicle has a warranty, and is called the money vehicle satellite. It is a negative incentive contract, meaning that if Boeing does not deliver a satellite by 1 April 2001, they owe the government $12.3M. In addition, there is a performance warranty, called Required On-Orbit Life, which means that once the satellite is launched, and begins to operate, there is a warranty for 12.7 years. There is also a guarantee on the ground software at the operational control segment at Falcon Air Force Base, which will be the Command and Control Arm of the Block IIF.

There are other management reform issues done under the acquisition reform window. It is an insight management type of program. One of the first major milestones was just achieved, called Preliminary Design Complete. The review took 25 minutes. By unit cost, Block IIF is a cheaper satellite compared to the other satellites. There are 52 best-value items in the satellite for which Boeing has signed. The satellite has an additional payload capacity of about 250 pounds, 260 watts.

Under the Integrative Master Schedule, every Monday they go to Boeing to go through the Master Schedule, to make sure that they are on track towards a particular major milestone. They use a system called GEMS. GEMS is a paperless database system for document transfer. Boeing uses that system to deliver primarily engineering documents – amazing success in terms of review time on documents. A team is co-located at Boeing which sits with their engineers and testers. They have a risk management program which categorizes the risk, and that risk is managed on a daily basis.

Boeing is responsible for the design of the satellite. They will have full responsibility for both the satellite and the ground control. Right now, Lockheed Martin Federal Systems designs the software for Block IIR and Control Systems Corporation (CSC) designs the software for Block IIF. In 2000, all that transfers to Boeing as a single integrating prime.

One of the things they will be able to do with Block IIF satellites is cross-linking, between not only IIF satellites, but IIRs and IIAs as well. The navigation payload will provide a three meter user range error, with a 1 meter goal. It will primarily be done through satellite operations such as cross-linking. The IIF is slated to ride the EELV (launch vehicle) in 2001.

The Reserve Auxiliary Payload is an additional 250 pounds with260 watts of additional space and power on the block IIF satellite. The additional payload will have to fit within that particular allocated spot and have the associated power with it. The GPS RAP Allocation Board is a high level board that looks at potential payloads to ride on the satellite. Once they determine that the payload has merit, it is given to Boeing to do a feasibility study to identify any impact on any satellite missions.

They are looking at advanced clock technologies to plug into the RAP. They have rubidium and cesium clocks and need to look at advanced clock technologies like hydrogen mazers. They are moving towards EELV, but hope to retain the Delta 2 as a backup. EELV will not be ready to meet GPS needs until December 2001.

Questions:

Rolf Johannessen asked for an explanation of dynamic risk management.

Answer:

First, in that risk management process, they identify if there is a risk, especially a technical risk. They have metrics against each of the areas of risk. There is a process to work it through risk mitigation. It is an iterative type of process, so that when a solution is found for a risk, it is monitored so that the risk is alleviated or even eliminated.

Gerald Cook, Sequoia Research asked if the three hours maximum age of data for the cross-link update is done totally autonomously or if it is a cross-linking of something that came from the ground or generated by the satellites.

Answer:

You don't get direct contact with the satellites every three hours.

GPS System Improvements
Hank Skalski, DOT representative at Air Force Base Command

There are two ways to look at the accuracy measurements. One is the User Range Signal (URA), which is the signal in space, and the other is the Spherical Error Probability, the SEP is the signal that the receiver sees. For SPS users, lack of availability is the biggest factor right now that degrades the accuracy of the signal.

There have been some improvements in this area already. The USNO has located their alternate master clock at Falcon. It is being connected to the GPS system itself so that the timing uploads are more accurate. The more accurate clocks that are on the satellites, the better the positioning and timing data is from the satellites. The control station makes contact with the satellite several times a day. The better the Kalman filter works, the better the information the satellite has on its position, and the more accurate the signal will be. The atmosphere affects the signal, as does selective availability.

There are some initiatives at the Air Force to look at and improve the accuracy of the basic GPS signal. The two prime programs that the Air Force is conducting are the Accuracy Improvement Initiative (AII), and Autonomous Navigation (AUTONAV).

AUTONAV will use cross-linking between satellites. The AII program will improve accuracy by improving the satellite position reporting and increasing the number of satellite contacts. The Air Force is totally committed to this and has funded $23M of the $26M needed to do AII. These improvements in accuracy in the AII program are all within the control segment and the satellites themselves, so there is no need for changes to the receivers.

One of the things they are doing to improve on this is to increase the number of ground stations. Right now the Air Force is talking with NIMA (the old DMA) to incorporate the monitoring of their signals into the basic ground control segment. The more monitoring, the more accurately they can look at the signals, and better determine of the status of the Constellation. They are also looking to improve the Kalman filter. The better the output from the processing, the better the NAV message. They also want to use a shorter message to upload information to the satellite, because the less you talk to the satellite, the more availability you have.

The AUTONAV program gives the ability for the ground stations to talk to more satellites. Right now, to send a message to the satellites, they have to wait until the satellites are in view of the ground stations. AUTONAV and cross-linking provides the ability to talk to satellites that are not in view of the ground stations by sending messages satellite to satellite. It improves the efficiency of the ground system.

In the area of SEP, they are looking an accuracy of about 2.5 meters, after incorporating all the improvements. Another benefit to AUTONAV and Cross-link is that the system will operate autonomously a little while longer. They are looking to operate for up to sixteen days without uploads at approximately the 16 meter accuracy level.

To SPS users, this means nothing until SA is turned to zero. With SA turned to zero and the AII program on board, there should be an increase in accuracy URE to 1.5 and 4.0 for SEP. Under full AUTONAV, there will be 2.5 meter accuracy, with about 6 meters in the vertical mode.

The AII program will begin in 1998, with all full accuracy improvements by the year 2002.

Questions:

Ed McGann asked if there were any studies on the effects to integrity.

Answer:

These particular initiatives do not include broadcast of an integrity message. These are purely accuracy improvements. There is no intent in these programs to transmit an integrity message, as the WAAS would be doing.

GPS Modernization is looking at the future of the positioning, navigation, and timing signal.

GPS Interference Testing Approval Working Group
Hank Skalski

The GPS Interference Testing Approval Working Group (GPSITAWG) consists of representatives from nearly all of government. They are working with the Department of Defense and the Joint Chiefs of Staff to improve the process, and to identify the focal points of who is going to communicate with whom. The FAA is responsible for that portion of the spectrum, so, by law, they are the focal point for the coordination with DOD. The next step is to incorporate the FAA's process with the Coast Guard's process to see how they work together, and what changes and improvements need to be made to make it work between those two entities.

The FAA and the Coast Guard are probably the most critical part of this from a safety aspect. Once those two systems work together, the next step will be to incorporate the rest of the government. So far, this is just addressing the approval part of the process.

The next step is the dissemination of that information to notify the proper people that there may be a service interruption in their area.

Questions:

Henry Baird asked if GITA was looking at international notification.

Answer:

Since the DOD activities are all within the continental United States, and/or its territories and waters, the only international notification will be that typical for aviation or maritime users - Notices to Mariners and Notices to Airman.

Mr. Skalski encouraged the membership to talk with the people in their countries to consider doing something similar, because their Ministries of Defense might be planning their own activities.

Mr. Preiss suggested the U.S. DOD could use its military channels to encourage its allies to take the appropriate steps.

Open Discussion

Franz Van der Kop stated a concern about the robustness of the GPS system with the upcoming solar storms.

Rebecca Casswell stated there will be a report from Air Force Space Command on that at the September meeting.

Rolf Johannessen requested a presentation on the sensitivity of a communications network to GPS. He would like to see a graph showing how the capacity of the communications network will drop if the performance of GPS deteriorates. And to what extent the communications network will suffer if the local reference stations were interfered with or were jammed.

(1) There was an issue raised a year ago to have in the SPS specification, a specification on velocity error in SPS. (2) At the same meeting, there was a request for information on the nominal GPS Constellation which Falcon is trying to maintain.

(1) **Rebecca Casswell** stated that the GPS velocity issue was forwarded to Space Command, and will be put in the next revision of the Signal Specification.

(2) **Karen Van Dyke** said that same issue came up in RTCA Special Committee 159. They did receive an almanac from the JPO dated July 1993 that is published in the WAAS MOPS in an appendix. At that time, that was the most current information that the JPO was willing to give them.

Heywood Shirer, who is working on the Federal Radio Navigation Plan, might be helpful on that too.

Karen VanDyke, Department of Transportation Volpe Center, said there is a Presidential Commission that is addressing critical infrastructure protection, and that GPS is one of the things that they have identified. They are looking into the vulnerabilities of GPS and also a number of other systems, especially systems that are related to each other, and certainly communications would fall into that.

Also Dr. Lewandowski reported that some GPS satellites that were unhealthystill had a healthy status in the code. The Volpe Center would be very interested in obtaining more information about that, especially working on GPS integrity issues. It would be very helpful to also obtain data on these integrity problems with the GPS Constellation, if that is indeed what it was.

Hank Skalski asked attendees to go back to their countries or companies to solicit input for the future modernization of GPS. It will be on the NIS Web Page. If you want to provide detailed information with some formulas, figures, and numbers, that is great. If you want to send a one-liner, saying: “why doesn't GPS do something?”, that is good, too.

Lt. Barker talked about 2SOPS and NANUs. The Guardian Tiger '97 is looking for input on whether the NANU is useful as is. Mr. Canny sent a letter to Air Force Space Command asking to formalize NANUs and work the issues. Since then, the questionnaire has gone out on the bulletin board. Go to the bulletin board, look for that form, provide input.

Preliminary discussions are in May and June, where all the people tasked to come together to decide all the issues.

Lt. Barker said they are trying to figure out if there is a test on Monday with a backup date for Tuesday, how quick does the civil side need to be notified it will be done on Tuesday. They have no direction on how quick they need to be.

Hank Skalski asked also for input to the formal interference testing approval process.

Ed McGann asked if this was an all-forces request going out about the need for information, and if the Navy, the Army, and NATO were participating.

Sally Frodge, DOT, said the mobile satellite services/GPS report from RTCA Special Committee 159 is now published. She encouraged the membership to look at it, analyze it, and see how it will impact yourself, your constituency, and whoever you represent. This may seem far in the future, but the systems are being launched into orbit now, and if there is an interference problem with these systems, it needs to be identified very quickly.

George Preiss said a few meetings ago that there was a statement that the warning for normal planned outages should be not less than 14 days.

Lt. Barker replied they had no formal guidelines. The try to get it out within 72 hours, because the COMMs Center can take up to 72 hours.

George Preiss stated that we need to know how sensitive we are to time synchronization problems, and satellites are to solar flares. He wondered if we should consider generating a request for a simple procedure which any civil organization can use, to inform the operators that there is a period of time when the system should be left alone.

He would like a presentation on the process from the time that the satellite is delivered, by Boeing, to the warehouse, onto a rocket, up into space, to what happens to it after it is dead.

In view of incidences, perhaps accidents, where GPS is involved, but not necessarily to blame for it, there should be a way to get an official certification of serviceability, so that there is immediate evidence that can be got hold of, and provided to the accident investigation team.

Mr. Preiss then asked the status of the issue concerning harmonization of GPS and GLONASS time frames.

Heywood Shirer, DOT, said following Initial Operational Capability of the GPS, any planned outages would require at least a 48-hour notice to both the Coast Guard and the Federal Aviation Administration.

Lt. Barker said the brief cradle to grave is: When the satellite gets to the test bed in Florida, there is compatibility testing with MCS. After launching into orbit, it is monitored, set in a COMM filter, data is analyzed, and if the clocks are stable, and the navigation message is stable, it is set to healthy. Once it comes to the end of its useful life, they do a Delta V to boost the satellite out of orbit. They burn all remaining fuel and try to get all the power from the satellite. It is pretty much space junk. It is not boosted too far out of the Constellation, but far enough to where it won't hurt us the future.

Karl Brown asked for better coordination between the CGSIC and the Federal Geodetic Control Subcommittee.

Mike Savill asked that the CGSIC issues be put on the Web Page.

CAPT Doherty asked the membership to use the issue forms. These forms are used to build future meetings.

Meeting Closing
Joe Canny, Deputy Assistant Secretary for Transportation Policy and CGISC, Chair

The GPS Capstone Requirements process needs civilian sector input. DOD is looking to the Department of Transportation to coordinate that. Please send your input to the Navigation Center, or to Hank Skalski himself.

DOT and DOD are still working through the second civil frequency issue. That issue is also being addressed in part, in the context of the Capstone Requirements effort. They recognize the desirability of having a fully coded second civil frequency, which is free from interference or Defense requirements. They will try to get it in place and operating as early as possible during the deployment of the Block IIF Constellation.

The third issue was the Gore Commission's recommendation that there be a civil sector outreach effort. His recommendation would be that the CGSIC be viewed generally as meeting that requirement to the extent that there are some additional consultation processes, higher level representation from agencies, whatever it may be that the commission had in mind. I would like to try. If feasible, he would like to do some fine tuning to accommodate that recommendation. The reasons for that are: First, to avoid setting up another organization. But, equally important, the CGSIC has a tremendous reservoir of history and expertise for dealing with the kinds of issues that are of concern to the Gore Commission.

Those are three critical areas requiring mutual follow-up during the months ahead. Mr. Canny thanked everyone for coming..